

TEACHING AND LEARNING OF PHYSICS IN
NEW ZEALAND HIGH SCHOOLS

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By

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DEDICATION

To my mother for her on-going love and support and to my late father who unfortunately didn't stay in this world long enough to see his son become a doctor.

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ABSTRACT

The main aim of this study was to gain insight into physics education in the New Zealand education system. The study sought insight into policies and practices that might promote excellence in physics teaching practices and also improve the number of students, and possibly teachers, involved. It also investigated how approaches to teaching high school physics in New Zealand influence students' perceptions of physics and their consequent desire to continue with physics studies beyond high school level. The study also investigated whether tertiary study adequately prepared and allowed pre-service teachers to become effective in their job. The overarching research question formulated to guide the study was: What are the current practices for teaching physics in New Zealand high schools and how might they be improved if they are not effective?

The study was underpinned by the constructivist theory and cognitive apprenticeship model. The reason is that students must be active participants and engaged in their own learning in order for meaningful learning to occur. Constructivism as a theory, has evolved from not only learning about declarative knowledge (knowing what) but also knowing "how and when" to learn in different ways. Accordingly, the teacher acts as a facilitator or mediator of learning rather than someone who only takes on the role of imparting knowledge. The cognitive apprenticeship model also presumes that learners should be exposed to the teaching methods that give students the chance to observe, engage in, invent, and discover expert strategies in context. Accordingly, the teaching methods should systematically encourage student exploration and independence.

The convergent parallel design (Creswell & Clark, 2011) of this study used mixed methods, including a national survey of physics teachers throughout New Zealand, a student survey, as well as classroom observations and interviews with high school physics teachers, high school students and initial teacher educators who were coordinating the physics education programmes. The sample size for the study comprised 104 high school physics teachers across New Zealand; 85

high school physics students from selected schools in Christchurch; and three physics teacher educators in three selected universities.

Data from teachers and students' survey questionnaires were analysed using descriptive statistical methods (including percentages, means, standard deviations and graphs where appropriate) and inferential statistics – independent samples test and multivariate analysis of variance (MANOVA). Audio recordings from interviews were transcribed and coded into nodes which provided easy retrieval of the themes that emerged. Detailed descriptions of classroom observations/practices were also recorded as a reference for indicating what actually occurred. The cases were compared for similarities and differences.

The research findings indicate that generally, physics classroom dialogue tended not to support constructivist epistemology or inquiry based teaching and learning. Student-centred instructional approaches were not common in many physics classes. The use of more traditional teaching approaches for physics contributed to students thinking that physics is a difficult subject and not something they want to participate in further. Some students in this study took physics because it is a requirement for future qualifications such as for engineering or medicine.

The findings of the study also indicated that there was a lack of alignment between the aspirations of the *New Zealand Curriculum (NZC)*, which promotes inquiry-based approaches to teaching and learning, and how physics is actually being taught. The teachers who participated in the research however, believed that several factors hindered the quality teaching and learning of physics at high school. The teachers believed that physics teaching in New Zealand is driven by assessment, not by student interests, and that schools place too much emphasis on performance and grades. The teachers felt that their ability to focus on improving teaching and learning was compromised by the time spent addressing assessment requirements.

Findings from the study also provided insight about physics teachers' preparation and indicated that the physics education programmes for would-be physics teachers generally do not

cover content knowledge for the subject. That is, the would-be physics teacher education programmes are primarily about pedagogical content knowledge (PCK). The teachers perceived that their initial teacher qualification did not adequately prepare them to teach some of the content areas now in the curriculum. Also, there is no national teacher education curriculum and teacher education providers have the freedom to design their own courses.

Among other things, the findings from the research lead to a conclusion that the emphasis on high stakes assessment has led teachers to concentrate more on the assessment tasks for senior physics students rather than on preparing inquiry-based lessons that would facilitate conceptual change and stimulate students' interest in the subject. The teachers considered that limited time to work with students and assessment demands, with its heavy workload, had worsened the problem of finding time to prepare interesting physics lessons.

Based on the findings from the research, seven recommendations were made. Teachers' ability to focus on improving teaching and learning, through innovative approaches, was compromised by the time spent addressing assessment requirements. Current assessment practices and high teacher workloads need to change so that teachers can spend more time to prepare interesting lessons and to explore topics in greater depth, thereby, helping to develop students' interest to learn physics more. The subject could be made less demanding by reducing the number of topics/concepts covered in the senior levels. After all, the *NZC* stresses that schools should keep assessment to levels that are manageable for both students and teachers.

PUBLICATIONS AND PRESENTATIONS ARISING FROM THIS THESIS

Buabeng, I., Conner, L., & Winter, D. (2015). The Lack of Physics Teachers: “Like a Bath with the Plug out and the Tap half on”. *American Journal of Educational Research*, 3(6), 721-730.

Buabeng, I., Conner, L., & Winter, D. (2015, April). *The lack of physics teachers*. Paper presented at the National Association for Research in Science Teaching (NARST) Annual International Conference, Chicago, IL, U.S.A.

Buabeng, I., Conner, L., & Winter, D. (2015, April). *Preparing physics teachers for the classroom: The role of initial teacher education providers*. Paper presented at the American Educational Research Association (AERA) Annual Meeting, Chicago, IL, U.S.A.

Buabeng, I., Conner, L., & Winter, D. (2014, July). *Physics teachers’ perceptions of their initial teacher education*. Paper presented at Australian Science Education Research Association (ASERA) Conference, Melbourne, Australia.

Buabeng, I., Conner, L., Winter, D., & Walker, L. (2013, September). *Augmented reality in physics teaching*. Paper presented at the New Zealand Institute of Physics conference at Nelson, New Zealand.

CHAPTER 1

INTRODUCTION

Background to the Study

The study of physics is crucial to understanding the world around us, the world inside us, and the world beyond us (Gibbs, 2003). In many respects, physics is the most basic and fundamental natural science - it involves universal laws and the study of the behaviour and relationships among a wide range of important physical phenomena (Cutnell & Johnson, 2007). It encompasses the study of the universe from the largest galaxies to the smallest subatomic particles. Moreover, it is the basis of many other sciences, for example chemistry, oceanography, seismology, and astronomy. All are easily accessible with a bachelor's degree in physics (American Physics Society, 2008). The physics learning experiences in schools provided by physics teachers, to which New Zealand is no exception, are therefore very important.

Researchers over the years have maintained that teachers form a strong causal factor in defining the quality of education in schools (Archibald, 2006; Darling-Hammond & Baratz-Snowden, 2005; Golla, de Guzman, Ogena, & Brawner, 1998; Hake, 1998). Teachers see to it that students have acquired creative and critical thinking abilities ready to face the realities of life. Central to acquiring creative and critical thinking abilities is the ability of teachers to design teaching sequences that develop among the students the abilities to respond to situations that beset them in aspects that make their learning meaningful (Darling-Hammond & Baratz-Snowden, 2005). This suggests that teacher' abilities to create an enabling atmosphere that allows meaningful classroom interaction with students cannot be underestimated. More so, the types of classroom interactions created by the teacher and the types of questions he/she uses to structure the teaching play an important role in the kinds of thinking skills learners employ, the range of

information to be covered and the thinking skills they may learn (Darling-Hammond & Baratz-Snowden, 2005; Smart & Marshall, 2012).

In 1996, in the U.S.A., the National Research Council's National Science Education Standards put forward five assumptions about science teaching, including the belief that, "What students learn is greatly influenced by how they are taught" (National Research Council, 1996, p. 28). Moreover, in the same year the standards called for a pedagogical shift from a teacher-centred to a student-centred instructional paradigm. It was held that a more student-centred approach to learning engages students in socially interactive scientific inquiry and facilitates lifelong learning. Also, there is considerable evidence to suggest that a move towards pedagogies involving full interaction, collective reflection and the development of consensual knowledge would lead to improved learning and attainment (Darling-Hammond & Baratz-Snowden, 2005; Moraru, Stoica, & Popescu, 2011; Smart & Marshall, 2012).

Science teaching (including physics) worldwide has standards which must be followed if the national or specific objectives of science education are to be achieved. Bybee, Carlson-Powell, and Trowbridge (2008) identified six components of a model for standard science teaching in the USA:

1. teachers of science should plan inquiry-based programmes for their students;
2. teachers should interact with students to focus and support their inquiries, recognize individual differences and provide opportunities for all students to learn;
3. teachers should engage in on-going assessment of their teaching and resulting students' learning;
4. conditions for learning should provide students with time, space, and resources needed for successful science learning;
5. teachers should foster habits of mind, attitudes, and values of science by being good role models for these attributes; and

6. teachers should use technology and mathematics to improve investigations and communications (p. 176).

To ensure effective teaching, using these standards, researchers have recommended the use of the constructivist 5E instructional model (engagement, exploration, explanation, elaboration and evaluation) which engages students in all aspect of inquiry-based learning (Bybee et al., 2008; Keser, Akdeniz, & Yyu, 2010). Even though the above standards were derived from American science education specifications, they are by no means limited to the U SA alone. These same standards could be potentially useful in science classrooms worldwide.

Teaching and Learning by Inquiry

With regards to effective methods of instruction (also called effective pedagogy) in the teaching of physics, a number of methods have been suggested in the literature. Prominent among them are inquiry-based teaching, activity-based teaching, guided discovery, demonstration and expository teaching. Though all these methods, and many others, are recommended, inquiry-based learning and guided discovery have been praised for requiring the students to do more than just report on a topic (Bencze, Alsop, & Bowen, 2009; Cahyadi, 2007; Centre for Inspired Teaching, 2008; McDermott, 2001; McDermott & Shaffer, 2000; Sokoloff, Laws, & Thornton, 2007).

Furthermore, the 2011 TIMSS report stressed that students can meaningfully build upon their knowledge and understanding of science through the process of scientific inquiry and therefore commended countries that have been engaging students in this process (International Association for the Evaluation of Educational Achievement [IEA], 2012). This is a wake-up call for other countries to place considerable emphasis on teaching and learning of science through inquiry-based processes. Science with physics in particular, is best practiced through active engagement and inquiry into the physical phenomena in the world.

Effective learning of physics (learning with understanding) is described as a type of learning in which learners take responsibility for their own learning through active construction and

reconstruction of their own meanings for concepts, events, experiences and phenomena (Brass, Gunstone, & Fensham, 2003). Thus, learning with understanding recognises the extent to which students engage with and maintain constructivist ways of learning, i.e. through active participation, learners take control of their own learning. Research findings suggest that much of students' learning in physics does not involve them in developing conceptual understanding (Brass et al., 2003; Freitas, Jiménez, & Mellado, 2004; Gunstone, Mulhall, & McKittrick, 2009). For example, Brass et al. (2003) found that, in Victoria, Australia, some high school and university teachers were more focussed on what their students could not do. Hence the idea of effective learning being students taking control of their own learning was rejected. Also, Freitas et al. (2004) concluded in their study, conducted in Portugal that some teachers still see their role as transmitting the knowledge they have to their students. Hence most often, teachers presented solutions to students rather than asking questions. Memorization of what the teacher has previously transmitted was prevalent and that "students write down in their daily notebooks everything that the teacher says" (p. 120).

Research has found that if students do not exercise control or responsibility over their own learning, their understanding of concepts and their attitude to learning are negatively affected (Brass et al., 2003). Effective learning thus occurs when learners have knowledge of their own learning, are aware of their own learning and seek to control their own learning and relate the knowledge acquired to the physical world. Learning by inquiry engages students actively in the construction of their own knowledge.

Context of the Study

Like many other countries, the education system in New Zealand is a three-tier model which includes primary schools, followed by secondary schools (high schools) and tertiary education at universities and/or polytechnics. In New Zealand high schools are classified and rated into socio-economic bands called ‘deciles’. The decile rating of a school reflects the average family socio-economic backgrounds of the students at that school. In other words, deciles represent the average number of socially and economically disadvantaged students at a school. There are 10 deciles with decile 1-3 being the most disadvantaged and decile 8-10 the least. Though deciles are a funding mechanism and in no way reflect the quality of education offered in that school, evidence suggests that parents often judge schools on their decile rating and many at times associate deciles with the success of a school. Analysis of the National Certificate of Educational Achievement (NCEA) results shows that the least disadvantaged schools (decile 8-10) always outperform their counterparts (New Zealand Qualifications Authority[NZQA], 2012a). Among other things, this study investigated teaching and learning practices in physics classrooms and took account of the decile rating of the schools.

Science is one of the eight learning areas that the *New Zealand Curriculum (NZC)* specifies as important for a broad, general education for every child (Ministry of Education, 2007). In the science learning area, students are expected to explore both how the natural physical world and science itself work so that they can participate as “critical, informed and responsible citizens in a society in which science plays a significant role” (Ministry of Education, 2007, p. 17). In addition, the *NZC* describes five key competencies as dispositions for learning – thinking; communication (using language, symbols and text); managing self; relating to others; and participation and contributing which align with the 21st century learning skills - integration of information technology, and developing children’s skills in collaboration, communication, critical thinking and creative problem solving (Conner, 2014a).

The *NZC* defines effective pedagogy as “teacher actions that promote student learning” (Ministry of Education, 2007, p. 34). Teachers use the *NZC*, together with the qualifications framework, to design their own learning programmes to meet the needs of their communities and students (Education Review Office, 2012; Ministry of Education, 2007). The *NZC* emphasises the importance of creating and encouraging reflective thought and action; enhancing relevance; facilitating shared learning; making connections to prior learning and experience; providing sufficient opportunities to learn; and inquiring into the teaching and learning relationship. All of these are key elements of inquiry-based learning. Thus, when students are taught by inquiry, individuals are actively engaged with others in attempting to understand and interpret phenomena for themselves thereby improving performance.

To make this achievable, the *NZC* encourages schools to keep assessment to levels that are manageable and reasonable for both students and teachers. The *NZC* further stresses that, “not all aspects of the curriculum need to be formally assessed, and excessive high-stakes assessment in Years 11-13 is to be avoided” (Ministry of Education, 2007, p. 41). However, little is known, about how teachers are incorporating the aspirations of the *NZC* and the 21st century learning skills into physics teaching and learning.

Rationale for the Study

For many years, educational underachievement has been associated with many factors, for example socioeconomic and language background factors. However, there is increasing evidence to suggest that teacher and teaching quality is a prevailing predictor of students’ achievement (Darling-Hammond, 2000, 2006; Darling-Hammond & Baratz-Snowden, 2005; Ell & Grudnoff, 2013; IEA, 2012).

Policy makers in New Zealand have over the years, defined quality teachers as being those who form effective learning relationships with students and teach in culturally appropriate and responsive ways, and are able to overcome all other influences on student achievement (Ell &

Grudnoff, 2013). The authors, based on their findings, commented that to improve student achievement and/or eliminate under achievement, the quality of teaching should be improved.

To improve the quality of teaching, Darling-Hammond and Baratz-Snowden (2005) outlined three general intersecting areas of knowledge that beginning teachers must acquire, and this has implications for what is included in initial teacher education programmes. Firstly, knowledge of learners and how they learn and develop within a social context; secondly, understanding the subject matter and curriculum goals (skill to be taught) in light of the social purposes of education; and thirdly, understanding the teaching in light of the content and learners to be taught, as informed by assessment and supported by a productive classroom environment (Darling-Hammond & Baratz-Snowden, 2005, p. 5). The general areas are summarised in Figure 1 below.

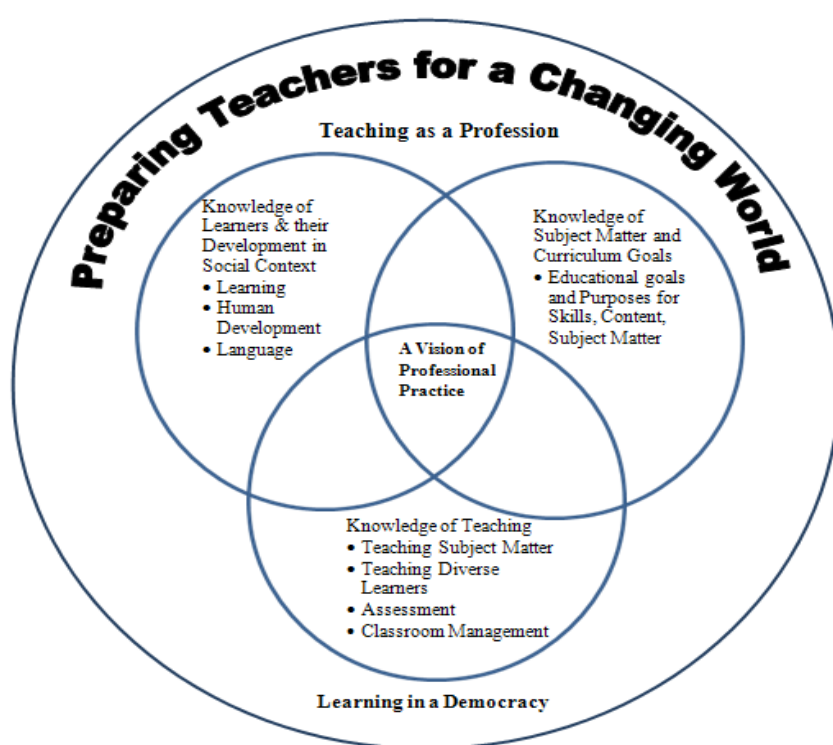


Figure 1. Framework for understanding teaching and learning (Darling-Hammond & Baratz-Snowden, 2005, p. 6). Reproduced with permission from the authors (Appendix N).

The authors argued that for beginning teachers to be effective in “managing the classroom, selecting appropriate tasks, guiding the learning process and maintaining children’s motivation to learn” (ibid, pp. 9-10), they need to be equipped with subject matter content knowledge, knowledge of teaching and knowledge of learners and their development. This idea has also been applied to initial teacher education, i.e. that initial teacher education programmes should model this by assessing individual student teacher’s needs in terms of content and modelling processes. In part, this study was guided by ideas from the understanding teaching and learning (UTL) model (Darling-Hammond & Baratz-Snowden, 2005) which outlined the three general intersecting areas of knowledge.

In order to achieve the above objectives, Darling-Hammond (2006) in her paper “*Constructing 21st-Century Teacher Education*” described three important component qualities that teacher education providers should be concerned with. These are: tight coherence and integration among papers and between coursework and practicum teaching work in schools; extensive and intensively supervised teaching work integrated with coursework using pedagogies that link theory and practice; and closer, proactive relationships with schools that serve diverse learners effectively and develop and model good teaching (p. 300). She contends that schools of education have to design programs to help prospective teachers to understand teaching and learning so that they can enact these understandings in the classroom.

Though the New Zealand education system is attending well to the qualities (McGee, Cowie, & Cooper, 2010; Piggot-Irvine, Aitken, Ritchie, Ferguson, & McGrath, 2009), McGee et al. (2010) indicated that the issue of coherence and integration remains a challenge for teacher education providers in New Zealand. They argue that there is no specific agreement about the core content of teacher education qualifications amongst different providers and the organisational and teaching arrangements for student learning experiences. They stressed that teacher educators have divided opinions over these matters. This therefore suggests that beginning teachers who enter the

classrooms may have varying degrees of training from different teacher education providers and therefore different ways and styles of teaching, despite the fact that all qualifications must demonstrate how students have been provided with experiences to meet the Graduating Teachers' Standards. The problem arises when they are expected to interpret and implement the school curriculum as enshrined in the *NZC* (Ministry of Education, 2007).

The need to provide relevant knowledge and understandings that are contextually and pedagogically appropriate is indispensable (Bailey et al., 2011; Loughran, Berry, & Mulhall, 2012). Physics is crucial to understanding the world around us and therefore teacher educators and physics educators in particular, should plan activities not only to increase teachers' abilities to teach the subject, but students' interest as well. Teaching high school physics requires creativity, thought and understanding not only of physics but also psychology, cognition and communication (Cornell University, 2011). In other countries, for example USA, national standard documents call for science disciplines subjects to be experienced and learned in ways that reflect how they are practiced in the real world (Loucks-Horsley, Stiles, Mundry, Love, & Hewson, 2010). Just as teacher education programmes should reflect what is known about learning and teaching, they should also reflect the Nature of Science.

The importance of context in science teaching and learning and successes of science education in New Zealand have been reported (Bull, Gilbert, Barwick, Hipkins, & Baker, 2010; Coll, Dahsah, & Faikhamta, 2010; Cowie, Jones, & Otrell-Cass, 2011; Stewart, 2011). Even though the practice of science education research in New Zealand has changed over the last century, "there is little evidence on how science is taught in schools" (Bull et al., 2010, p. 31). Also, in a comprehensive report on the state of primary and secondary school science education in New Zealand, Vannier (2012) articulated that curricular materials that support science remain in schools, but the professional supports that enabled teachers to find and effectively use these materials have diminished over the years. In its quest to improve science education in schools, the

Science Advisory Committee of the Office of the Prime Minister identified the following five key challenges and actions:

1. creating opportunities for communities to discuss the purposes of science education at different levels during schooling;
2. developing alliances between teachers and scientists to understand the impact of the changing nature of science research on science education;
3. enabling effective science education in primary schools by identifying the needs of primary teachers around science instruction and how to meet them;
4. understanding the diverse needs of upper secondary students and engage secondary and tertiary groups toward this goal; and
5. addressing the challenge of raising the performance of low-achieving students, many of whom are Māori and Pasifika (Vannier, 2012, p. 22).

The report stresses that these challenges will be met by engaging all stakeholders and using evidence to make decisions. In order to come up with the evidence, however, research needs to be conducted to better understand how teaching and learning take place.

Statement of the Problem

There is global concern about the number of students pursuing physics at both secondary and tertiary levels and the number of graduates wanting to be trained as physics teachers (Institute of Physics [IOP], 2010; PhysTEC, 2014). In 2013, the National Task Force on Teacher Education reported that “the need for qualified physics teachers is greater now than at any previous time in USA history.” (PhysTEC, 2014). The decline in interest in the subject has led to the closure of some physics departments at universities (Blickenstaff, 2010). This decline in the numbers of students taking physics could be due to a combination of factors including the perception that physics is a ‘hard’ subject with low levels of student achievement; the perceived nature of the

subject as being highly mathematical and abstract; and how the subject is taught at the high school level.

A number of reports on students performance and classroom practices in New Zealand have identified some areas of concern including little time for science, few hands-on activities, teachers with insufficient knowledge of subject matter and confidence in science instruction and students with less interest for science (Bull et al., 2010; Cooper, Cowie, & Jones, 2010; Hipkins & Bolstad, 2005; Hipkins, Roberts, Bolstad, & Ferral, 2006; Vannier, 2012). More so, with physics education in particular, a lot of concerns have been raised globally regarding overall student achievement, students' interest in continuing to study physics, intellectual engagement, and the low number of prospective physics teachers coming through the education system. (see for example Blickenstaff, 2010; Buabeng, 2012; Buabeng & Ntow, 2010; Fischer, 2011; Murphy & Whitelegg, 2006a, 2006b; Pockley, 2013; Thacker, 2003). In Australia, Pockley (2013) reports the measures outlined by physicists to reverse the “worrying decline” (p. 10) in the number of students taking physics.

It would not be unreasonable to speculate that those factors accounting for this worrying development may include teaching methodology, teacher qualifications and teacher education programmes, instructional resources, teachers' and students' attitude towards physics, psycho-social learning environments and teaching and learning support systems, among many others. It would be intriguing, therefore, to investigate issues concerning the teaching and learning of the subject and the reasons why students would or would not continue further studies in it.

Purpose of the Study

The study, which was focussed on high school physics education in New Zealand, sought insight into policies and practices that might promote excellence in physics teaching and also improve the number of students, and possibly teachers, involved. It also investigated how approaches to teaching high school physics in New Zealand influence students' perceptions of physics and their consequent desire to continue with physics.

The study also sought insight into the course structure, course components and programme requirements for physics education in New Zealand. More importantly, it investigated whether the tertiary study adequately prepared and allowed pre-service teachers to become effective in their job.

Overarching Research Question

The overarching research question to drive the study was: What are the current practices for teaching physics in New Zealand high schools and how might they be improved if they are not effective?

Specific Objectives

From the overarching research question the following objectives were put forward to drive the study.

1. investigating how senior high physics teachers are educated in New Zealand;
2. understanding the conceptions held by physics teachers about teaching and the relationship between teachers conceptions about teaching and their teaching practice;
3. understanding professional learning and development services for physics teachers, for both those who are physics majors and those who teach physics but who do not have a degree in physics;
4. obtaining senior high school physics teachers and students perceptions about classroom practices and how they are related to effective learning;
5. investigating factors constraining the teaching and learning of physics and the dwindling number of students involved; and
6. exploring ways to improve teaching and learning of high school physics and the number of students (and possibly teachers).

Research Questions

From the overarching research question and the objectives, the following research questions were formulated:

1. What is emphasised in the initial teacher education of high school physics teachers in New Zealand and why?
2. a. What are the conceptions about teaching held by New Zealand high school physics teachers?
b. How do these conceptions influence their teaching practice?
3. How do secondary teachers and students perceive their physics classroom interactions?
4. What on-going professional learning do the teachers receive, if any, and how effective they are, for the teaching and learning of physics?
5. What factors, if any, do secondary teachers and students perceive as constraining the quality of teaching and learning of physics in New Zealand?
6. What changes do secondary teachers and students perceive need to occur to make physics more interesting to learn?

Significance of the Study

This study was an attempt to explore the practices that might enhance excellence in physics teaching and learning in the New Zealand education system, including challenges and recommendations for future policies. The study attempted to survey the actual classroom teaching and learning practices in order to have ‘on the spot evidence’ about how teaching and learning of the subject takes place. Research of this type, which examines high school physics teachers’ initial teacher education training, instructional pedagogies/methods, professional learning and the activities which go on in physics classrooms has rarely been undertaken (Bull et al., 2010). Therefore, as far as New Zealand is concerned, this is a ground-breaking study. The findings from

this study contribute to a better understanding of the content knowledge, pedagogical content knowledge and strategies physics teachers have and might benefit from for teaching physics.

The findings of this study have highlighted practices in physics classrooms and how high school students perceive the subject in New Zealand. The findings may serve as a catalyst for innovations in physics teaching, which may in turn enhance physics learning and the number of students involved. The findings also serve as a basis for offering useful suggestions to all stakeholders in science education. They could also be useful in discussions about professional development of high school physics teachers. Furthermore, the study makes an important contribution to enhance greater participation in the teaching and learning of physics. Another significance of the study is that the findings can be used to compare current methods and procedures of teaching and learning of the subject (physics) with international standards. The findings open the door for improvement in the teaching of physics, to take physics learning to a higher level. The findings also inform future policies and practices and identify significant areas for further studies. Additionally, the study serves as resource material for students/researchers who may make a related study in the future.

Operational Definition of Terms and List of Abbreviations

Achievement standards	-	refers to what a student of Year 12 and 13 must be able to achieve in order to gain credits towards national qualifications (NCEA).
Alternative teacher preparation programmes	-	other routes into teaching apart from the traditional college and university-based teacher education programmes.
Contextual constraints	-	school parameters and/or conditions that have negative influence on teaching and learning.

Effective pedagogy	-	teaching strategies that support intellectual engagement, connectedness to the wider world, supportive classroom environments, and recognition of individual differences.
Initial teacher education	-	refers to the preparation of pre-service teachers.
Physics education course	-	the contents to be studied over a specific period as determined by the respective institution.
Physics education programme	-	the study of the course(s) leading to the award of the qualification at the respective institution.
Pre-service teachers	-	used interchangeably with student teachers, prospective teachers, and aspiring teachers to refer to those undertaking an initial teacher education programme.
Quality teaching and learning	-	the kind of teaching that promotes student intellectual engagement and learning.
Student-centred instruction/approach -	-	methods of teaching that shift the focus of instruction/activity from the teacher to the learners. Learners are required to actively think about or process information.
Teacher-centred instruction/approach -	-	teaching approaches where most of the class time is spent with the teacher lecturing and the students watching and listening. The students work individually on assignments, and collaboration is not encouraged.

UC Education Plus	- A department that provides professional development programmes and advice to teachers and educators
AR	- Augmented Reality
CAM	- Cognitive Apprenticeship Model
ERHEC	- Educational Research Human Ethics Committee
ICT	- Information and Communications Technology
ILD	- Interactive Lecture Demonstration
ITE	- Initial Teacher Education
NCEA	- National Certificate of Educational Achievement
NZC	- New Zealand Curriculum
NZTC	- New Zealand Teachers Council
NZQA	- New Zealand Qualifications Authority
OECD	- Organisation for Economic Co-operation and Development
PBI	- Physics by Inquiry
PEEL	- Project for Enhancing Effective Learning
PD	- Professional Development
PhET	- Physics Education Technology
PI	- Peer Instruction

Organisation of the Rest of the Thesis

The remaining chapters of the thesis are organized as follows:

Chapter 2 discusses the literature related to the study. The review involves theoretical and empirical studies related to the problem under study.

The third chapter describes the methodology used in the study. Specifically, the research design, the research instrument, sample and sampling technique, the procedures for data collection and the data analysis are discussed.

The analysis and presentation of the quantitative and qualitative data are presented in chapters 4 and 5 respectively. In chapter 6, the main focus is the discussion of the research questions in relation to the findings from both the quantitative and qualitative data.

Finally, the summary, conclusions, implications, recommendations and areas for further research are presented in chapter 7.

CHAPTER 2

REVIEW OF RELATED LITERATURE

The research sought to gain insight into physics education in the New Zealand education system. It explored physics teachers' initial teacher education and practices that might promote excellence in physics teaching and also improve the number of students and possibly teachers, involved. It also investigated how approaches to teaching high school physics in New Zealand influenced students' perceptions of physics and their consequent desire to continue with physics studies.

Over the years, physics education has been tainted with persistent low enrolment figures and low numbers of physics teachers coming through the education system. Investigation into the teaching and learning of physics is therefore necessary for raising awareness of the issues canvassed, which may indicate issues to be addressed, perhaps through policy, as well as leading to an improvement in physics instruction/teaching and achievement. The review is thus presented and discussed under sub-headings as follows: theoretical framework; beliefs and conceptions of physics teachers about physics; nature of physics classroom practices; teaching and learning of physics – conceptual change and problem solving; preparing physics teachers for high/secondary schools; initial teacher education effectiveness; professional development for teachers; and purposes and practices of assessment in teaching and learning.

Theoretical Framework

The study was underpinned by two theories – constructivism and cognitive apprenticeship model.

Constructivism

Constructivism is characterized by the view that knowledge is not transmitted directly from one person to another, but is actively built up by the learner (Cobern, 1998; Driver, Asoko, Leach,

Scott, & Mortimer, 1994). Cobern (1998) argues that constructivism is an avenue of research that directs attention to the role of culture in the learning process. Cobern writes that students come to the classroom with a variety of world-views and preconceptions and such views must be acknowledged. He believes that a constructivist classroom is one in which people are working together to learn. To him, such a classroom will be a place where inquiry is conducted. Discourse will be the mode by which participants engage in negotiations of meaning. Cognitive, social and cultural differences among students will be honoured and alternative world-views respected (Cobern, 1998).

Conner (2014b) also accentuates that a constructivist classroom is a learner-centred environment which acknowledges and brings to the fore the past experience of students. She articulates that in constructivist classrooms, learning is “reflective, interactive, inductive and collaborative, and questions are valued as a source for curiosity and focus for finding out information” (p. 3). Constructivism as a theory, has evolved from not only learning about declarative knowledge (knowing what) but also knowing “how and when” to learn in different ways (Conner, 2014b). In such classrooms, the teacher acts as a facilitator or mediator of learning rather than someone who only takes on the role of imparting knowledge.

Theories of cognitive development. Over the last two decades, many learning theories, including the cognitive development theories of Piaget, Vygotsky and Bruner, have been implemented in different instructional models in learning environments. Piaget indicated that social interactions create disequilibrium to encourage growth in knowledge. He emphasized that the individual learners construct their knowledge through the process of adaptation – which can be accomplished in two ways: (1) accommodation, where existing schemes are modified so that new information can fit in, and (2) assimilation, where new information is modified to fit in the existing schemes. (Eggen & Kauchak, 2013; Hoy, 2010). According to Piaget, social interactions

can reinforce this mechanism but it is the learners themselves who play the major role in developing their knowledge.

Vygotsky, on the other hand, promoted the dominant influence of social interactions. In his well-known sociocultural learning theory. Vygotsky suggested that social interaction leads to continuous step-by-step changes in learners' thought and behaviour that can vary greatly from culture to culture (Hoy, 2010). This learning process involves three key elements – culture, language and “zone of proximal development”. Vygotsky believed that when learners interact with peers they can actively participate in dialogues, discover how others think about their experiences and then incorporate the ways others interpret the world into their own ways of thinking. By this way, learners are able to develop their knowledge towards more complex and sophisticated structure (Eggen & Kauchak, 2013; Hoy, 2010).

Bruner also suggested that instruction follows a sequence of three stages. The basic stage is called enactive stage where learners manipulate objects to learn about the world around them. The next stage is iconic stage where learners represent experiences and objects as concrete images. In the last stage, the symbolic stage, learners are able to think in abstract terms with symbols (Cahyadi, 2007). The principle of progressing towards a higher level of thinking process has a lot of applications. Two prominent ones are the spiral curriculum (where concepts are developed from simple forms involving concrete objects and experiences to a high level of abstraction) and discovery learning (where learners work from examples to find general principles on their own (Cahyadi, 2007).

The ideas in these cognitive learning theories are in line with constructivism in the sense that learners construct their knowledge and/understanding on their own, rather than knowledge being transmitted by someone else. Though these theories have been used in different instructional models in learning environments, constructivist theory has been found to be more related to instructional methods, and can be used to improve teaching in certain scientific subjects taught in

schools to which physics is no exception. It encourages students to use active techniques (e.g. experiments, real-world, problem solving) to create knowledge, reflect on, talk about what they doing and how their understanding is changing (Conner 2014b; Keser et al., 2010). The constructivist theory of learning also applies to teachers' learning when learning to teach.

Cognitive Apprenticeship Model

The cognitive apprenticeship model also presumes that learners should be exposed to the teaching methods that give students the chance to observe, engage in, invent, or discover expert strategies in context (Berryman, 1991; Collins, Brown, & Holum, 1991). According to Berryman (1991), the teaching methods should “systematically encourage student exploration and independence” (p. 5). Berryman stresses that teachers only coach – “offering hints, feedbacks, and reminders; provide ‘scaffolding’ (support for students as they learn to carry out tasks); and ‘fade’ – gradually handing over control of the learning process to the student” (p. 5). More so, the learning environment should reproduce the technological, social, time, and motivational characteristics of real world situations with varying levels of difficulty to enable students to work with their peers in finding solutions to problems as experienced in the real world (Berryman, 1991; Chandra & Watters, 2012).

Empirical studies show that the cognitive apprenticeship model and/or constructivist theory is an accurate description of how learning occurs and the instructional strategies can be designed into formal learning contexts with positive effect (Chandra & Watters, 2012; Conner, 2014b; Dennen & Burner, 2007; Keser et al., 2010). With these two theories (constructivist and cognitive apprenticeship) teachers acknowledge they cannot mandate what students learn. They design learning activities that are informed by what students already know and believe, and actively encourage students to reflect on and manage their own learning.

Beliefs and Conceptions of Physics Teachers about Physics

The New Oxford Dictionary of English defines belief as an acceptance that a statement is true or that something exists; something one accepts as true or real; a firmly held opinion or conviction (Pearsall & Hanks, 1998). An inspection of other dictionaries and entries also brings out the meaning of belief as:

.... a state or habit of mind in which trust or confidence is placed in some person or thing; conviction of the truth of some statement or the reality of some being or phenomenon especially when based on examination of evidence (Woolf, 1974);

... the feeling of being certain that something exists or is true (Sinclair, 1993) ... a strong feeling that something is right or good; an idea that you are certain is true (Rundell & Fox, 2002);

... the feeling of certainty that something is true (Cambridge University Press, 2008).

In short, belief can be understood as the psychological state in which an individual holds a proposition or premise to be true (Cahyadi, 2007).

The Oxford dictionary and Merriam-Webster dictionary also define conception as: a complex product of abstract or reflective thinking; the sum of a person's ideas and beliefs concerning something; and the originating of something in the mind (Pearsall & Hanks, 1998; Webster, 2006).

In science education research, conceptions of teaching can be defined as:

The set of ideas, understandings, and interpretations of experience concerning the teacher and teaching, the nature and content of science, and the learners and learning that the teachers used in making decisions about teaching, both in planning and execution (Hewson & Kerby, 1993, p. 7).

Drawing from Pajares (1992) general research into teachers' beliefs, Mulhall and Gunstone (2008, p. 439) noted that "beliefs travel in disguise and often under alias – attitudes, values, opinions, perceptions, conceptions, implicit theories, explicit theories, and perspectives." Various labels

have also been used to refer to teachers' conceptions, such as, views, beliefs practical personal theory, orientation, and cognitive structures (Buaraphan, 2007; Gess-Newsome, Southerland, Johnston, & Woodbury, 2003; Hewson & Kerby, 1993; Koballa, Glynn, & Upson, 2005; Tsai, 2002). Even though there seem to be subtle differences in the meaning of the labels, Tsai (2002) used these labels interchangeably. In this study, conceptions, beliefs and views are used interchangeably in the report to describe participant teachers' understanding and experiences about teaching and how these inform their teaching.

Generally, what people know and believe influences their actions and informs the choices they make in their everyday lives. Beliefs also inform how teachers engage in and go about their classroom practices (Loucks-Horsley et al., 2010). Teachers' conceptions about how science is developed may be potentially related to their beliefs about how to teach science and how students learn science, including physics. Gallagher (1991) described the views of the nature of science held by 25 experienced secondary science teachers in Michigan State, USA, as "unsettling" (p. 124). Classroom observations showed that all the teachers emphasized science as a body of knowledge, spent more time in developing terminology than on building relationships across concepts and rarely engaged students in laboratory work.

Tsai (2002) investigated science teachers' conceptions about teaching, learning science and the nature of science. Research data were gathered through interviews with 37 secondary school science (physics and chemistry) teachers. Results from the study showed that most science teachers had 'traditional' beliefs about the teaching and learning of science – science is best taught by transferring knowledge from teacher to students (e.g. transferring of knowledge, giving firm answers, providing clear definition, giving accurate explanations, presenting the scientific truths or facts).

Using the Maryland Physics Expectations (MPEX) Survey and Reformed Teaching Observation Protocol (RTOP), Mistades (2006) also investigated beliefs about physics teaching

held by three physics teachers (faculty members) of the De La Salle University in the Philippines, and sought to determine how many of these beliefs translated into classroom strategies and practices. Findings from the study showed that teacher's beliefs influence their actions and practices in the classroom. The physics teachers who participated in the study viewed learning physics as primarily understanding underlying ideas and concepts rather than simply focusing on memorizing equations and formulae. The classroom observation data, obtained using the RTOP, supported this view as they (teachers) scored highest (83.3%) in the propositional content knowledge. Mistades indicated that the teachers' lessons highlighted fundamental concepts by giving specific examples, showing relationship between concepts, and moving from simple to complex problems.

As part of the research on teachers' knowledge and thought patterns (conceptions, beliefs and views) about teaching, some studies often make conclusions about teachers' practice but do not support these conclusions with observational data (Hashweh, 1996; Tsai, 2002). However, recent studies about teachers' conceptions and/or beliefs that included classroom observations found a relationship between their conceptions about teaching and learning science, their epistemological beliefs and their teaching practice (Ladachart, 2011; Mulhall & Gunstone, 2012; Tsai, 2007).

Mulhall and Gunstone (2008, 2012), for example, found that the approaches used by physics teachers to teach physics were generally linked to their views about learning physics. Mulhall and Gunstone used qualitative methodology to explore views about physics held by a group of physics teachers whose teaching practice was traditional, and compared them with the views held by physics teachers who used conceptual change approaches. Semi-structured interviews and observations were employed for this purpose. The authors discovered that the perception that particular physics teaching approaches may be linked to particular views about physics "seemed to apply to the traditional group but not to the conceptual group" (Mulhall & Gunstone, 2008, p.

456). Findings from the study suggest that the two groups of teachers had distinct views about learning physics:

The Traditional teachers thought of physics learning as the outcome of doing certain activities, and in terms of acquisition of information about physics ideas. For the traditional teachers, physics was seen as hard because it is mathematical and abstract, and many learners do not have the special attributes necessary to learn it. The conceptual teachers thought that learning involves cognitive activity by the learner, and that individuals construct their own understanding in terms of their personal frameworks. For the conceptual teachers, the ideas of physics were considered to be counter-intuitive and troublesome in terms of learning. They saw discussion as being important for learners as it helps tease out and develop understandings of physics ideas (Mulhall & Gunstone, 2012, p. 444).

In discussing the implications of the data collected, the authors indicated that traditional approaches to teaching physics, which often fail to promote adequate student understanding of physics ideas, still persist. The challenge then, reported by the authors, is to find ways of promoting teacher change, of helping physics teachers understand and implement ways of teaching that lead to better student learning.

Research on teachers' conceptions about teaching is framed within the constructivist perspective on teachers learning (Hashweh, 1996; Hewson & Kerby, 1993; Koballa et al., 2005; Ladachart, 2011). According to this perspective, it is believed that teachers process information and build cognitive structures about teaching based upon their prior experience which they have gained since their days as a student (Hashweh, 1996; Hewson & Kerby, 1993) and such cognitive structures can act as a point of reference for their current teaching practice (Koballa et al., 2005). Hewson and Kerby (1993) noted that teachers are likely to choose instructional approaches which are align with their conceptions about teaching so that they can achieve their teaching goals. Thus,

teachers' conceptions about teaching have a direct relationship with their teaching practice. Koballa et al. (2005) therefore contended that understanding of teachers' conceptions about teaching can be used as point of reference to understand their teaching practice. Even though such conceptions about teaching are often resistant to change (Buaraphan, 2007), Koballa et al. (2005) and Ladachart (2011) observed that, teachers are most often, likely to compromise their ideal and aspirational conceptions about teaching due to contextual constraints causing them to "hold working or back-up conceptions about teaching" (Ladachart, 2011, p. 177).

Given that teachers have their personal conceptions about teaching and these beliefs are likely to influence their instructional decision-making, this study, in part, explored the conceptions held by some physics teachers and examined them in the context of a constructivist epistemology.

Nature of Physics Classroom Practices

For students to have an expert understanding of scientific concepts, Vosniadou (2007) argues that students must undergo profound conceptual change. She recommends that instruction must address both the "need for individuals to construct their own understanding and the socio-cultural factors that are present in school settings" (p. 52). Even though many empirical studies have demonstrated that carefully planned, interactive instruction can be effective in promoting conceptual change and enhance performance (Cahyadi, 2007; McDermott & Redish, 1999; Redish & Steinberg, 1999; Thacker, 2003; Vosniadou, 2007; Wieman, Perkins, & Adams, 2008), findings from the literature show that many physics teachers continue to teach using the same old, ineffective, traditional, teacher-centred instructional approach (Angell, Guttersrud, Henriksen, & Isnes, 2004; Gallagher, 1991; Hackling, Goodrum, & Rennie, 2001; Tobin & Gallagher, 1987; Vosniadou, 2007)

For instance, in the late 1980's in Perth Australia, Tobin and Gallagher (1987) found that the most common instructional mode in high school science classes was whole class interactive – when the teacher dealt with the class as a whole, and interacted with one student at a time while

the others listened; and whole class non-interactive – comprised of lecture presentations followed by individual seatwork and small group activities. More than a decade later, Hackling et al. (2001) found that the teacher-centred instructional approach was still prevalent in many of the secondary schools in Australia:

For many secondary students, the teaching-learning process is teacher directed and lessons are of two main types: practical activities where students follow the directions of the teacher to complete an experiment, and the chalk and talk lesson in which learning is centred on teacher explanation, copying notes and working from an expository text. (Hackling et al., 2001, p. 8)

The extent of teacher-centeredness was revealed by 61% of secondary students who indicated that they copy notes from the teacher nearly every lesson and 59% also indicated that the teacher never allows students to choose their own topics to investigate.

A similar situation was described in high schools in Norway. Angell et al. (2004) administered questionnaires to 2192 students taking physics and 342 physics teachers in high schools in Norway and followed up with focus group interviews. They found that in relation to physics, proportionally a greater part of classroom time (about 60%), was spent with the teacher presenting new material on the blackboard/whiteboard. Physics classrooms were found to be dominated by “chalk and talk instruction” (p. 701). Though students in the study perceived physics as interesting and describing the world and everyday phenomena, they also perceived the subject as difficult/demanding, formalistic in nature and more mathematical as it uses the language of mathematics to express physical processes and phenomena. The majority of the students wanted a stronger emphasis on context and connectedness as well as qualitative/conceptual approaches that are student-centred. Based on the findings, the authors suggested that:

“...secondary physics education preparing students for tomorrow’s society should be characterized by variety, both within and among courses, integration

of mathematics in the physics courses, more pupil-centred instruction, and a stronger emphasis on knowledge in context. (p. 703)

In Germany, students at secondary level described physics lessons as “chalk-loaded demonstrations” (Tesch, Euler, & Duit, 2003, p. 1). Tesch et al. (2003) used a video study to identify patterns of instructional phases and interactions as well as to detect key indicators for conditions, processes, and beliefs that characterise the quality of physics instruction. They found that:

1. Limited and rigid questioning-developing strategy predominates in whole class discussions. Students have little voice in these phases;
2. Though experiments play a substantial role in instruction, students have little opportunity for planning, carrying out and interpreting the results of the experiments by themselves;
3. Opportunities for learning by cognitive activation are not often provided. Most teachers’ thinking about physics instruction is rather oriented on contents. Moreover, most teachers also do not hold a constructivist view about teaching and learning (Tesch et al., 2003, pp. 3-4).

It has also been shown that teacher interactions affect learners' attitude towards learning and their participation in class activities (Masika, 2011). Masika indicated that teacher interaction behaviours were an important aspect of the learning environment and are strongly related to high school student outcomes. Masika found that, in Kenya, physics teachers were autocratic and dominated their classrooms by talking only and sometimes talking with illustrations. The study recommended that an initiative involving teachers of physics in action research in the area of classroom interaction would go a long way in helping the teachers improve their teaching behaviour. Recently, using a mixed method approach, physics instruction in Alabama State was reported generally as teacher-oriented with lectures forming a significant part of the lesson (Sunil

et al., 2015). The authors indicated that the classroom observation data did not support teachers' references, during interviews, to their common use of hands-on-instruction.

One can infer from the above studies that teacher-centred instruction continues to be a widely used instructional strategy in secondary school physics classrooms. Moreover, students have expressed a desire for more interactive environments. In a teacher-centred approach, there is little opportunity, if any, for students to articulate their thinking, hear what others are thinking and examine those ideas (Crowe, 2007). At best, questions posed by instructors to individual students may be the limit of interaction in most physics classrooms. Remaining members of the class are not required to subject their own ideas to the type of scrutiny that might reveal any incoherence in their minds. The practical challenge consists of finding instructional methods that would help students to understand, accept and use current scientific views. Some of these methods have been reviewed below.

Teaching and Learning of Physics – Conceptual Change and Problem Solving

Dealing with Conceptual Change and Problem Solving

Research into students' understanding and learning of physics is prominent in the literature. Interest and motivation have been reported as essential factors for student learning and academic achievement (Hidi & Harackiewicz, 2000; Nolen, 2003). Science classrooms that focused on understanding and qualitative thinking were found to positively predict students' satisfaction with learning (Nolen, 2003). In physics education in particular, the motivation, active knowledge and participation of the students is of paramount importance. Passive, unmotivated students and minimal creativity in learning have a limited future in contemporary education (Ülen & Gerlič, 2012).

At the heart of physics education research is a shift in physics instruction from “What are we teaching and how can we deliver it?” to “What are the students learning and how do we make sense of what they do?” (Redish & Steinberg, 1999, p. 2). Over the years, physics education

researchers have used a variety of tools in trying to find out what students' real difficulties are and how to improve their achievement in the subject. The connection between physics and mathematics for instance, has been found as a major weakness to physics understanding (Angell et al., 2004; De Lozano & Cardenas, 2002; Gill, 1999; Orton & Roper, 2000). In order to make this shift achievable, Redish and Steinberg stress that teachers of physics need to listen to the students and find ways to learn what they (students) are thinking. By doing this, teachers then begin to make sense of how students learn physics in a way that helps them improve their courses to be more meaningful to students.

In their paper, "Teaching Physics: Figuring out What Works", Redish and Steinberg (1999) described one of such tools, to find out students' real difficulties, as "determining the state space" (p. 2). This approach, according to the authors, involves an interview with a number of students, letting them describe what they think about a particular situation or having them work through a problem. Thus, the students are encouraged to "think aloud" and to explain their reasoning. Ideally, the goal is not to help the students come up with the correct answer but rather to understand their thinking. The writers argument is that interviews often reveal new insights into the way students think about physics that are surprising even to the most skilled and experienced instructors.

Adding to this, McDermott (2001) extols that the focus of physics teaching must be on the students as learners. She underscores that close contact with students provides the opportunity to observe the intellectual struggles of students as they try to understand important concepts and principles. "Day-to-day interaction in the classroom has enabled us to explore in detail the nature of specific difficulties, to experiment with different instructional strategies, and to monitor their effect on student learning" (McDermott, 2001, p. 1128), reported by McDermott and her research team (Physics Education Group).

Research findings have indicated that the conceptual learning of physics often uses models, animations and simulations for problem solving approaches. For example, in teaching electric circuits, one model that has been proven effective is *Physics by Inquiry* (PbI), developed by McDermoth and her physics education group (see e.g. Afra, Osta, & Zoubeir, 2009; Akerson, Hanson, & Cullen, 2007; Breslyn & McGinnis, 2012; Campbell, Danhui, & Neilson, 2011). The PbI is a module with carefully structured experiments, exercises, and questions that are intended to engage students actively in the construction of important concepts and in their application to the physical world. As the students work through the module, they are guided in constructing a qualitative model for a simple circuit. In the process, specific difficulties identified through research are addressed (McDermott, 2001). She eloquently describes their experience:

Students work with partners and in larger groups. Guided by the questions and exercises, they conduct open-ended explorations, perform simple experiments, discuss their findings, compare their interpretations, and collaborate in constructing qualitative models that can help them account for observations and make predictions. Great stress is placed on explanations of reasoning, both orally and in writing. The instructor does not lecture but poses questions that motivate students to think critically about the material. The appropriate response to most questions by students is not a direct answer but a question to help them arrive at their own answers. (McDermott, 2001, p. 1129)

The Project for Enhancing Effective Learning (PEEL) in Melbourne, Australia is another example of a movement in education that directly responded to teachers' concerns about students learning, especially in the sciences. Though, it was developed as partly a consequence of traditional teaching, PEEL teachers view teaching as problematic and have become experts in developing procedures that are the direct opposite of transmissive teaching (Loughran et al., 2012). One experienced PEEL teacher, Rosemary Disting of Wesley College – Glen Waverley in

Melbourne, Australia, offered an extensive report of her efforts to move from teaching as telling to teaching for understanding. She indicated:

... my teaching had shifted from me doing all the work for the students to the students now working out part of the content for themselves. They had been provided with meaningful opportunities to think and I had not taught by telling... My understanding of what it meant to teach students to be active learners was being developed and I valued what was happening. (Dusting, 2002, pp. 177-180)

PEEL is a project which focuses on the teaching and learning practices in secondary school classrooms (Erickson, Brandes, Mitchell, & Mitchell, 2005). This project supports the “creation of classroom learning environments, which are more productive and enjoyable places for students and teachers alike in comparison to more conventional classrooms” (Erickson et al., 2005, p. 793). As stated by Lumb and Mitchell (2009), PEEL operates as a network of autonomous and voluntary groups of teachers who take on a role of interdependent innovators. The teachers agree to meet regularly to reflect on their practice, and to provide mutual support and stimulation for the processes of teacher and student change. Thus, coherence is provided by the shared concerns about passive, dependent learning and by the dissemination of information about the project and by structures that allow teachers to learn from and share new wisdom with teachers in other schools as well as a few academic friends.

PEEL’s achievements include the development of a repertoire of teaching procedures designed to promote effective learning; findings about the nature of student change, and teacher change; and findings about the nature of collaborative professional development in schools and between the school and tertiary sectors (Lumb & Mitchell, 2009). Having been founded in one secondary school in 1985, PEEL has since then spread to schools throughout Australia and to many other countries including the U.K., Canada, Sweden and Iceland (Erickson et al., 2005). PEEL’s large collection of ideas, strategies, procedures, support and resources, developed over a

long period of time, for science teachers have helped to improve upon their classroom practices, such as group work and assessment (Lumb & Mitchell, 2009). These collections are available online (<http://www.peelweb.org/index.cfm?resource=pip>) and both physics teachers and teacher educators can access them to inform better physics teaching practices and learning.

Interactive Teaching Approaches in Physics

The use of interactive teaching methods in the teaching and learning of physics is another most significant change in teaching methodology. One notable feature of these approaches is providing an environment where students are motivated to construct knowledge by themselves, rather than the knowledge being transmitted to them by their instructor as in the traditional approach (Hake, 1998). These methods have various labels such as interactive engagement, active learning and guided inquiry, and the constructivist theory of learning informs the philosophy behind the methods (Hake, 1998; Mazur, 1997). The term interactive teaching approach is used in this thesis to refer to those “methods designed at least in part to promote conceptual understanding through interactive engagement of students in heads-on (always) and hands-on (usually) activities which yield immediate feedback through discussion with peers and/or instructors” (Hake, 1998, p. 65).

This section discusses four of these interactive approaches: peer instruction (Mazur, 1997); interactive lecture demonstration (Sokoloff et al., 2007; Sokoloff & Thornton, 1997), photonics explorer (Prasad et al., 2012), and visual interactive computer software programs (applets, PhET and augmented reality) (Dünser, Walker, Horner, & Bentall, 2012; Ülen & Gerlič, 2012; Wieman et al., 2008). Physics teaching should include more student interactive approaches than the way it is now, and when physics is taught in this way, the subject would be made more accessible to all students (Wieman et al., 2008), especially those at secondary schools, thereby improving upon the number of students involved and possibly teachers as well.

Peer instruction. Peer Instruction (PI) is a widely used pedagogy in which lectures are interspersed with short conceptual questions, usually multiple-choice questions, called ConcepTests (Fagen, Crouch, & Mazur, 2002; Lasry, Mazur, & Watkins, 2008; Mazur, 1997). The PI engages students during class through activities that require each student to apply the core concepts being presented, and then to explain those concepts to their fellow students. Unlike the common practice of asking informal questions during a lecture, which typically engages only a few highly motivated students, the more structured questioning process of PI involves every student in the class. It modifies the traditional lecture format to include questions designed to engage students and uncover difficulties with the material (Crouch & Mazur, 2001; Mazur, 1997).

Results from ten years of teaching with PI, through true experimental-based research – where subjects are assigned randomly to intervention and control groups, (Crouch & Mazur, 2001) indicate an increased mastery of both conceptual reasoning and quantitative problem solving. Fagen et al. (2002) focused on assessing the effectiveness of PI via a web survey. The researchers polled PI users (teachers) to learn about their implementation of and experience with PI. The survey collected data about how instructors learned about PI, courses in which PI was used, implementation details, course assessment, effectiveness, and instructor evaluation. Out of the 700 instructors that completed the survey, 384 were identified as using the PI. The PI survey results indicated that most of the assessed PI courses produced-learning gains matched with interactive engagement pedagogies, and “more than 300 instructors (greater than 80%) consider their implementation of PI to be successful” (p. 208). Also, the majority (over 90%) of those using the method plan to continue or expand their use of PI.

Lasry et al. (2008) measured students’ conceptual understanding of Newtonian mechanics using the Force Concept Inventory (FCI) in both PI and traditional courses at John Abbott College (a two-year college) and Harvard University. The results showed that PI-taught students demonstrated better conceptual learning and similar problem-solving abilities than traditionally

taught students. They also found that, by engaging students on the course, PI reduces the number of students who drop the course. The researchers concluded that PI is an effective instructional approach not only at a top-tier university, but also at a two-year college. In both settings, PI increases conceptual learning and traditional problem solving skills.

Interactive lecture demonstration. The Interactive Lecture Demonstration (ILD) is designed to engage students in the learning process by converting the usually passive-student lecture and recipe lab environment to a more active one (Sokoloff et al., 2007; Sokoloff & Thornton, 1997). With the ILD, the instructor initially describes a demonstration to the class. Students record their individual predictions on a prediction sheet and engage in small-group discussions. Afterwards, they record their final predictions and hand in the prediction sheets to the instructor. The instructor elicits common students' predictions from the whole class. The instructor then carries out the demonstration, with measurement tools suitably displayed. A few students may be asked to describe and discuss the results in the context of the demonstration. The instructor may proceed with presenting analogous physical situation(s) with different "surface" features based on the same concepts (Sokoloff & Thornton, 1997, p. 340).

Through a pre-test and post-test experimental study, supplemented with questionnaires, Cahyadi (2007) conducted two case studies to investigate the effectiveness of the PI, and ILD approaches on students understanding of Newtonian concepts. The first case study took place at the University of Surobaya, Indonesia and the second study was conducted at the University of Canterbury, New Zealand. In the areas that she assessed (conceptual change and problem solving), the results showed that the experimental classes achieved significantly greater improvement in conceptual change compared to the control classes. Students in the experimental classes also performed significantly better in problem solving than those in the control classes.

Results from the second case study also produced a marked improvement in students' comprehension of learning materials as all the students welcomed the application of "new

elements of the instruction” (Cahyadi, 2007, p. 82). Even though the sample sizes for Cahyadi’s studies were large (341 for the first study and 198 for the second study) for an experimental study, the results were obtained with non-randomization of the subjects to the treatment conditions, indicating that the gains might have resulted from pre-existing differences between the groups. Galvan (2006) emphasized that in the school settings students are not normally assigned to the classes hence there may be “important pre-existing differences between the two groups, which may confound the interpretation of the results of such an experiment” (p. 45).

Photonics explorer. In order to solve the declining interest of students in science subjects, particularly physics, in Europe the European Union has initiated various projects to foster science education at European high school level. One of these projects is the Photonics Explorer Kit (PEK) which focuses on the development of an educational kit for light, optics and photonics (Cords, Fischer, Euler, & Prasad, 2012; Fischer, 2011; Prasad et al., 2012). The PEK is specifically designed to cover the topics that are in the curriculum in order to help the teacher and students to achieve educational targets – yet with the use of hands-on experiments in an inquiry-based learning context (Cords et al., 2012).

The photonics explorer project offers well prepared resources that can be integrated into the existing European curricula and which can also be easily integrated into other curricula. It does not take away teaching time but rather helps the teacher to make the best use of the time already designated for light and optics in their curriculum to ensure that educational targets are easily achieved (Cords et al., 2012). The experimental equipment in the kit has been specifically designed to support inquiry-based teaching and learning. The kit equips teachers with class sets of experimental materials related to optics and photonics within a supporting didactic framework consisting of worksheets, factsheets, teacher guides and multimedia material (videos, photos etc.) (Prasad et al., 2012). The kit consists of eight modules, four for lower secondary (12-14 yrs) and four for upper secondary (16-18 yrs). Each kit includes a class-set of experimental materials such

that a class of about 25 to 30 students can work together in small groups of three and four. It contains not only the components, worksheets and factsheets for conducting hands-on experiments but also a guide for the teacher with a suggested outline for the use of each module, and these save the teacher valuable lesson preparation time (Prasad et al., 2012).

From a pilot study in six school classes in Germany and five school classes in Belgium, the authors report that the approach has been very well received by both teachers and students. Many students are reported to have said that they appreciate the “additional freedom due to the ‘simplicity’ of the components to develop their own experimental setups far away from the regular step-by-step programme” (Cords et al., 2012, p. 72). The photonics explorer program aims at equipping science teachers in European secondary schools free-of-charge with up-to-date educational resources to really engage, excite and educate students about the fascination of working with light (Fischer, 2011). A teacher receives the kit free of charge once he/she attends a teacher training course on how to implement it in their classrooms. This is mainly to introduce teachers to the concepts of guided inquiry based learning and the importance of students doing the hands-on experiments themselves (Prasad et al., 2012).

Visual interactive computer software programs. The advances in computer hardware and software programs have provided new platforms for physics teaching and learning. One such program is *applets*, which have been running on the World Wide Web for the past decade. When an applet is oriented on a small, specific domain of physics, we talk about *physlets* (Ülen & Gerlič, 2012). Physlets are interactive materials, where processes happen at certain intervals and there is an interaction between the model and the student. Students have the opportunity of changing the conditions and immediately observing the impact. In addition, when dealing with new physical phenomena, students can change relevant parameters and immediately see the consequences of their actions. This can help students to understand the main concepts of the phenomenon. Ülen and Gerlič stress that due to the phases of physlets (illustration, exploration and problems), “they

can be used as an element of almost any curriculum with almost any teaching approach, so they could also play an important role in the conceptual learning of physics” (p141).

A similar model, which has been developed, tried and tested, to help develop students’ conceptual understanding of complex ideas with problem solving is Physics Education Technology (PhET) (Wieman et al., 2008). PhET is a collection of web-based interactive simulations for teaching and learning physics and other sciences as well. It was developed with three primary goals: “increased student engagement, improved learning”, thereby improving performance and “improved beliefs about and approach toward learning” (p. 394). These goals have been the critical areas for physics education research over the years (McDermott, 2001; Redish & Steinberg, 1999). The majority of the PhET simulations are physics-related and cover a range of topics from introductory material in mechanics and electricity and magnetism to advanced topics such as quantum mechanics, lasers, and magnetic resonance imaging (Wieman et al., 2008). The key features of PhET simulations, that is, visualization, interactivity, context, and effective use of computations are particularly effective for helping students understand the abstract concepts in physics (McKagan et al., 2008).

Another form of technology development for increasing student interaction has been augmented reality (AR). The AR technology has emerged as one of the interactive engagement approaches which provides visual and interactive experiences that allow in-depth understanding of abstract phenomena (Dünser et al., 2012). It provides physics educators with an exciting interactive environment to engage learners and enhances understanding of key concepts. What is different with regards to AR is that it provides the platform for both teachers and students to think about how to use technology to represent complex concepts. Thus, the learning materials (AR books) are developed by teachers and students themselves which in turn enhances greater understanding of the content (Dünser et al., 2012).

Using the software application BuildAR (HIT Lab NZ) as an educational tool for constructing AR scenes, Buabeng, Conner, Winter, and Walker (2013) interacted with a small group of pre-service secondary school physics teachers with constructed AR sequences. The aspiring physics teachers visualising the magnetic field about an inductor were able to fully immerse themselves in the three-dimensional projection of the field, thereby actively interacting with the physical phenomena in virtual space. The aspiring physics teachers were convinced that using AR as a teaching tool would facilitate an improved conceptual understanding of the underlying physics concepts.

All the interactive approaches mentioned above aim to encourage student interaction in physics classrooms and to focus students' attention on fundamental concepts. Involving students actively in the lesson, through these interactive teaching methods is likely to improve their conceptual understanding of physics concepts (Cahyadi, 2007; Lasry et al., 2008; Mazur & Hilborn, 1997; McDermott, 2001; McKagan et al., 2008). As observed by Brekke (2009), high school physics can be a great experience for students if some changes are made in the way the subject is taught. Brekke advises physics teachers to remember that most students gain knowledge when subject matter is tangible or real, therefore physics instruction should generally proceed from the concrete to the abstract, rather than other way around which is prevalent in many physics classrooms.

Preparing Physics Teachers for High/Secondary Schools

Research in education indicates that the success of science education reform depends on the preparation of teachers (Etkina, 2010; McDermott & Shaffer, 2000). Since the teacher mediates the science culture in the classroom, thereby setting environment conditions that might enhance student learning and interest (Juuti, Lavonen, Uitto, Byman, & Meisalo, 2010), the preparation of physics teachers has been a purposeful intellectual endeavour in many countries, institutions and universities. Hodapp, Hehn, and Hein (2009) argue that high-school physics teachers are one of

the most important factors in developing the science and technology workforce of the future. Therefore, they suggest, institutions of higher learning will need to dramatically increase the numbers of high-school physics teachers they educate. The authors indicate that the responsibility for that preparation cannot be left solely to education departments or schools of education. According to them physicists must work with colleagues in education to address the significant shortage of qualified physics teachers.

In 1999, the American Physical Society (APS), the American Institute of Physics (AIP), and the American Association of Physics Teachers (AAPT) jointly established the Physics Teacher Education Coalition (PhysTEC) to improve and promote the education of future physics teachers (www.phystec.org). Since then, PhysTEC has been working in collaboration with colleges and universities to identify and disseminate effective practical and innovative methods and to advocate for an enhanced role of physics departments in the education of future teachers (Hodapp et al., 2009). According to the authors, successful teacher programs span a continuum of effort – from the student recruitment to the post-graduation mentoring of those who eventually enter classrooms. Teachers, like other professionals, are not produced in a single act or even a single semester, they are rather developed over time and must be supported during the process. More importantly, the key to attracting and retaining students in a teacher education program is personal interaction.

The American Association for Employment in Education's (AAEE) report that physics teacher positions are the most difficult to fill in high schools (McLeskey, Tyler, & Flippin, 2004). Many universities have been encouraged to institute more proactive programs to train more physics teachers for high schools in the USA (Etkina, 2010). For example, the University of Arkansas is reported to have an exemplary program for physics teacher preparation which incorporates many of the above features. The university's graduates are reported to be the main source of high-school physics teachers for the region (Hodapp et al., 2009). The Physics Teacher Education Coalition (PhysTEC) program at Arkansas develops student interest in physics with inquiry-based

introductory courses, guides potential teachers through the licensure process, and mentors them during the early years of their professional lives. Arkansas also has a Learning Assistants program that has played a significant role in the recruitment and retention of new teachers. The PhysTEC report indicates that in the 10 years prior to 2001 when the project began at Arkansas, only one physics teacher graduated from the university. However, in the year 2004/05, 20 physics teachers graduated and there is no sign of that number diminishing. Hodapp et al. (2009) suggest that other institutions can emulate their counterpart institution by taking the following steps:

1. Talk to your students. Find out what motivates them and identify and encourage the ones who seem likely to become teachers. Give individual attention to future teachers and monitor their progress;
2. Make sure that a clear track is available for physics students who want to pursue teacher certification, and understand how it fits in with students' schedules;
3. Hold an open house, with refreshments, to advertise the teacher education program, and make sure that physics faculty inform their classes about the program;
4. Adopt interactive teaching methods in your introductory courses and provide talented students an opportunity to participate as peer teachers or mentors (Hodapp et al., 2009, pp. 42-43).

Collaboration is another vital issue which runs through most of the literature (see e.g. Etkina, 2010; Hodapp et al., 2009; McDermott & Shaffer, 2000; Orleans, 2007). Physics departments are advised to get involved in national issues if they want to address the shortage of physics teachers. According to Hodapp et al., an effective partnership between schools, universities and stakeholders can significantly magnify the impact of a physics teacher education program and develop broad support in the institutions. They further suggest, among other things, that institutions can;

1. Work with colleagues in the education department to streamline requirements placed on students who want to receive teaching certificate in physics or science. One specific action

would be to have courses on physics teaching methods count toward both a physics degree and teacher certification;

2. Collaborate with education department and other science departments on joint proposals to support future science students;
3. Invite education colleagues to speak to the departments on issues of concern and also participate on search committees;
4. Become or support a champion who builds and maintains teacher education programs. Department support may include relief from teaching courses, travel funds or consideration of teacher education support activities when making promotions and tenure decisions (Hodapp et al., 2009, p. 43) and
5. Existing physics students in universities could visit schools.

The University of North Carolina and Rutgers University are reported to have successfully implemented the above suggestions by building up a science teacher education program from scratch, with the goal of having students complete a science major with teaching certification in four years (Etkina, 2010; Hodapp et al., 2009). At Rutgers University, for example, Etkina (2010) reports on pedagogical practices and physics teacher preparation program. The program, according to Etkina, focuses on three aspects of teacher preparation – knowledge of physics, knowledge of pedagogy and knowledge of how to teach physics (pedagogical content knowledge). This is the new model used around the world (OECD, 2014). The philosophy of the programme and the coursework can be implemented either in physics departments or in a school/college of education.

Initial Teacher Education Effectiveness

Researchers over the years have assessed initial teacher education (ITE) programmes through the impact of both primary and secondary school teachers' (most often pre-service teachers) subject matter and pedagogical knowledge on classroom practice. ITE (also called pre-service

education) has been a major concern of many physics education researchers. The National Research Council (1996) recommended that teachers of science and mathematics should have a strong knowledge of science and mathematics concepts to enable them to guide students to explore these concepts. Research findings however, show that, it is difficult to measure the extent to which a large national sample of teachers understand the concepts they are teaching, hence proxy measures such as ‘major’ or ‘number of courses taken’ in one’s field are usually used (Weiss, Banilower, McMahon, & Smith, 2001). Teachers who have acquired sufficient academic preparation – usually subject matter content and pedagogical skills, are generally regarded as effective in classrooms (Darling-Hammond, 2000, 2006; Hendriks, Luyten, Scheerens, Slegers, & Steen, 2010; Orleans, 2007; Scheerens, 2009).

The Role of Content Knowledge

Initial teacher education plays a key role in supporting the development of effective teachers. Lederman and Gess-Newsome (2001) found that, despite the fairly high level of confidence pre-service teachers have in their subject matter knowledge and the attainment of a bachelor’s degree in the academic area, most do not understand the content that they are to teach in a conceptually rich or accurate manner. In discussing how the nature of science content affects learning and teaching, Fensham, Gunstone, and White (1994) indicated that content, learning and teaching are interrelated. To them, the extent to which teachers will go about a particular task in the classroom is greatly influenced by the subject matter content they know. Advancing on this, Gunstone (1994) suggested that content knowledge is important for “metacognition purposes” (p. 145). He argued that, understanding the science subject matter content, for physics in particular, is most important for pre-service teachers, in the sense that it promotes self-reflection amongst them about their learning and how and what others have learned.

Conner and Gunstone (2004) noted that learning outcomes are maximised when content knowledge is promoted together with strategic learning approaches. All these have implications

for ITE in that ITE programmes need to model how to identify and learn content knowledge for pre-service teachers so they will gain confidence to teach the fundamental aspects of physics. ITE providers are responsible for the training and development of effective teachers. Commenting on the role that science teachers can play in facilitating high school students' learning, Wellington and Osborne (2001) indicated that "as teachers of science ... our primary skills lie not in our ability to do science, but in our ability to interpret and convey a complex and fascinating subject" (p. 138). This statement indicates the importance of subject matter content knowledge (Fensham, 2001) and how beginning teachers might be enabled to interpret and connect ideas and make these explicit in their teaching.

McDermott (2001) found that in the USA, a science degree programme majoring in physics does not provide adequate preparation for teaching in high schools. McDermott emphasized that the scope of topics and the laboratory courses offered by most physics departments rarely address the needs of student teachers. Likewise, Mohd Zaki (2008) found that in Malaysia pre-service teachers had a weak conceptual understanding of Newtonian concepts, and had difficulty understanding kinematics graphs. Similar observations have been made by other researchers (Cochran-Smith, 2005; Darling-Hammond, Chung, & Frelow, 2002; Fensham, 2004; Korthagen, Loughran, & Russell, 2006). This has led to various attempts to reorganise teacher education programs. Korthagen et al. (2006) for example, after analysing effective features of teacher education programs in Australia, Canada and Netherlands, outlined how to guide the development of teacher education programs that are responsive to the expectations, needs and practices of student teachers. Also, Fensham (2004) argued that in developing appropriate pedagogies, the problematic nature of the content itself should not be ignored. This means that when educating physics teachers, we need approaches that are specific to the content domain of physics (Mohd Zaki, 2008).

The Shortfalls – Figuring Out What Works and What Doesn’t Work

McDermott and Shaffer (2000) argued that a well-prepared teacher of physics or physical science should have, in addition to a strong command of the subject matter, knowledge of the difficulties it presents to students. The authors, through a series of classroom observations and interviews with pre-service and in-service teachers, found that traditional courses in physics do not provide the kind of preparation that teachers need to teach physics at secondary school level. They indicated that teachers tend to teach as they were taught – “if they were taught through lectures, they are likely to lecture, even if this type of instruction is inappropriate for their students” (p. 72).

They (McDermott & Shaffer, 2000) argued further that, although the content of the high school physics curriculum is closely matched to the introductory university course, the latter does not provide adequate preparation for teaching the same material in high schools. The authors emphasize that the breadth of topics covered and the laboratory courses offered by most physics departments also do not address the needs of students, in that most of the time the equipment used in universities is/are not available in high schools, and no provision is made for showing teachers how to plan laboratory experiences that utilize simple apparatus. In discussing the implications of the study, the authors noted that separation of instruction in science (which takes place in science courses) from instruction in methodology (which takes place in education courses) decreases the value of both for teachers. They emphasized that effective use of a particular instructional strategy is often content specific, hence if teaching methods are not studied in the context in which they are to be implemented, teachers may be unable to identify the elements that are critical. Thus they may not be able to adapt an instructional strategy that has been presented in general terms to specific subject matter or to new situations.

Among many other things, McDermott and Shaffer (2000) recommended that teachers should study each topic in a way that is consistent with how they are expected to teach that material. In

addition, they stressed, teachers also need to be given the opportunity to confront and resolve their conceptual and reasoning difficulties, not only to improve their own learning but to become aware of the difficulties that their students might have.

Through a survey of about 3000 beginning teachers (from both teacher education programmes and alternative teacher preparation programmes), Darling-Hammond et al. (2002) examined the teachers' perceptions of their preparedness and their sense of teaching efficacy. These variables are found to correlate with student's achievement (Darling-Hammond, 2000; Darling-Hammond, Berry, & Thoreson, 2001). Findings from the study showed that teachers' overall preparedness to teach related significantly to their sense of efficacy about whether they are able to make a difference in student learning. The results indicated that teachers who felt better prepared were significantly more likely to believe they could reach all of their students, handle problems in the classroom, teach all students to high levels, and make a difference in the lives of their students. And those who felt underprepared were significantly more likely to feel uncertain about how to teach some of their students and more likely to believe that "students' peers and home environments influence learning more than teachers do" (Darling-Hammond et al., 2002, p. 294).

In discussing the findings, the authors noted that the teachers' feeling of preparedness was also significantly related to their confidence about their ability to achieve teaching goals. They concluded that measures must be put in place to improve teacher education programmes. They cited quality control standards by the National Council for Accreditation of Teacher Education (NCATE) as one of those measures that can be used to improve initial teacher education programmes.

The professional learning of student teachers has been attributed to three major sources of influence, namely pre-training education experiences, teacher education coursework and fieldwork in the teacher education programme (Cheng, Cheng, & Tang, 2010; Kagan, 1992; Levin

& He, 2008). These authors assert that the practicum experience and the variability of this experience influence teaching preparation. In New Zealand, most secondary teachers complete a one-year graduate diploma, which includes supervised practicum experience in local high schools. Most of these teachers complete their first degree in their respective subject specialisms. The subject specific degree is deemed to provide most of the content knowledge required for at least one specialist-teaching area. Thus, the ITE physics course is primarily about acquiring pedagogical content knowledge (PCK). Findings from the Teaching and Learning International Survey (TALIS) 2013 results indicate that teachers whose initial education included content, pedagogy and practice elements specifically for the subjects they teach reported feeling better prepared for their work than their colleagues without this kind of training (OECD, 2014).

Though the New Zealand education system has been reported to be attending well to developing understandings of the teaching and learning processes, teacher educators continue to have divided opinions over the subject matter knowledge that should be included in teacher education qualifications (McGee et al., 2010). There is an opportunity to review what subject matter content knowledge is included in ITE programmes as New Zealand explores shifting its entry qualification to be at Masters level. Recent international studies about effective approaches to teaching and learning, such as findings from the OECD Innovative Learning Environments (ILE) Project (OECD, 2013) mean that adjustments to initial teacher education are required to accommodate the needs of current day learners and what we know makes a difference to learning. Recently, Conner and Sliwka (2014) indicated the implications of the ILE work for initial teacher education. The authors argued that initial teacher education should adhere to the “seven transversal learning principles” (pp. 165-166) if prospective teachers are to be effective in their learning environments in which they will be expected to teach. Thus, significant changes are imminent in the initial teacher education programmes in New Zealand.

Professional Development for Teachers

In more general terms, professional development (PD) is the means by which individuals are supported to know more about the job they do and how to do it better. Mizell (2010) refers to PD as different types of educational experiences associated with one's profession. He stresses that people from many different professions partake in PD to pick up new information and skills to improve their performance. For teachers, professional development can be defined as "activities that develop an individual's skills, knowledge, expertise and other characteristics as a teacher" (Scheerens, 2009, p. 22). Thus PD is an on-going process throughout one's working life. Loucks-Horsley et al. (2010) assert that PD consists of teacher learning opportunities designed and implemented with the purpose of helping students to achieve standards. Also, Borko (2004) describes PD as teachers' learning experiences that are essential to improve and enrich their knowledge of the subjects they teach. Expanding on this assertion by Borko, Mizell (2010) argues persuasively that, college and university programs do not provide all the knowledge essential for graduates to become effective teachers, they however learn through experience – through professional development.

In education, studies have shown that for teachers to be as effective as possible and to be able to improve upon quality teaching and also stay on the job, they (teachers) need to constantly develop their knowledge and skills through PD. Using data from a survey conducted by the National Centre for Education Statistics of the US Department of Education, Ingersoll (2003) identified that large numbers of teachers leave the profession due to the complex nature of teaching. He mentioned that one-third of teachers leave the profession within three years and 50% leave within five years. As indicated by Mizell (2010), teachers are often faced with challenges in terms of subject content, new instructional methods, advances in technology, changed laws and procedures, and student learning needs. Professional development must therefore serve as a source

of information to inform teachers and keep them abreast of new teaching strategies, skills, content, and changes in standards and/or curriculum (Bucher, 2009; Mizell, 2010).

The need for PD for teachers has been extensively reported in the literature. In the USA for example, PD is one of the most important pillars for supporting science education. Reports from the US 2000 national survey of science and mathematics education showed that most of the science teachers were not well prepared for the challenges in the classroom and in substantial need of PD in a number of areas (Weiss et al., 2001). The researchers reported that almost 60% of elementary and middle school teachers indicated a need for professional development on how to use inquiry-oriented teaching strategies. Whereas 67% percent of middle school science teachers reported a need to deepen their own science content knowledge, 71% also pointed out the need to deepen their understanding on how to use technology in science instruction. In order to upgrade teachers' knowledge and skills, most of the projects funded by National Science Foundation (NSF) and US Department of Education were often teacher enhancement projects that focus on improving teacher knowledge and skills (Banilower, Heck, & Weiss, 2007).

Elements of Teacher Professional Development

Professional learning opportunities for teachers are seen as improving instruction and students' achievement. Using the multiple conceptual and situative perspective approaches, Borko (2004) identified three phases of research on teacher PD that can have a positive impact on teacher learning. She explains that Phase 1 research focuses on a single professional development program at a single site which seeks to understand the relationships between the teachers' participation in the professional development program and their learning. In Phase 2, a single PD program enacted by multiple facilitators is studied to seek insight into the relationships among facilitators, the professional development program, and the teachers as learners. Different PD programs, situated at multiple sites are studied and compared in Phase 3. In conclusion, Borko noted that the majority of today's professional development studies are all Phase 1 research. She revealed that Phases 2

and 3 helps to study and compare the relationships among all four elements of a professional development system: facilitator; professional development program; teachers as learners; and context. To inform professional development policies and practices, she suggested that more attention be given to Phases 2 and 3.

Reporting on what makes PD effective, Garet, Porter, Desimone, Birman, and Yoon (2001) contended that PD activities that focus on mathematics and science content areas have an important positive influence on changes to teaching practice. Similarly, professional development programs that focus on “subject-matter knowledge and on student learning in that subject area are more likely to have an impact on student learning than those that focus on more generic topics” (Banilower et al., 2007, p. 377). The authors also stated that providing teachers with opportunities to deepen their content and pedagogical knowledge in the context of high-quality instructional materials would improve their classroom instruction, which would in turn lead to higher student achievement. Other researchers, for example Blank and de las Alas (2009), Blank, de las Alas, and Smith (2007), Darling-Hammond and Richardson (2009), and Hill (2009) have also stressed that professional development that focuses on developing the pedagogical skills of teachers to teach specific kinds of content has a strong positive influence on practice and student learning and achievement. In a review of 25 PD programs across states in the USA for science and mathematics teachers, Blank et al. (2007) found that 22 of the programs focused on content knowledge. Most of the programs were also positively rated for providing pedagogical content knowledge for the teachers.

As outlined above, PD is seen as one of those strategies for improving teachers’ competencies and students’ achievement. Bucher (2009) emphasized that a good student academic achievement and better educated nation and society is the ultimate goal of education and to be able to achieve this, teachers’ competencies in the content areas they teach should be of paramount interest to all educators. Thus, the need for an increase in teacher content knowledge and pedagogical skills

should be not be disregarded. Bucher uses the figure below to explain how education is reformed through the gains from PD.

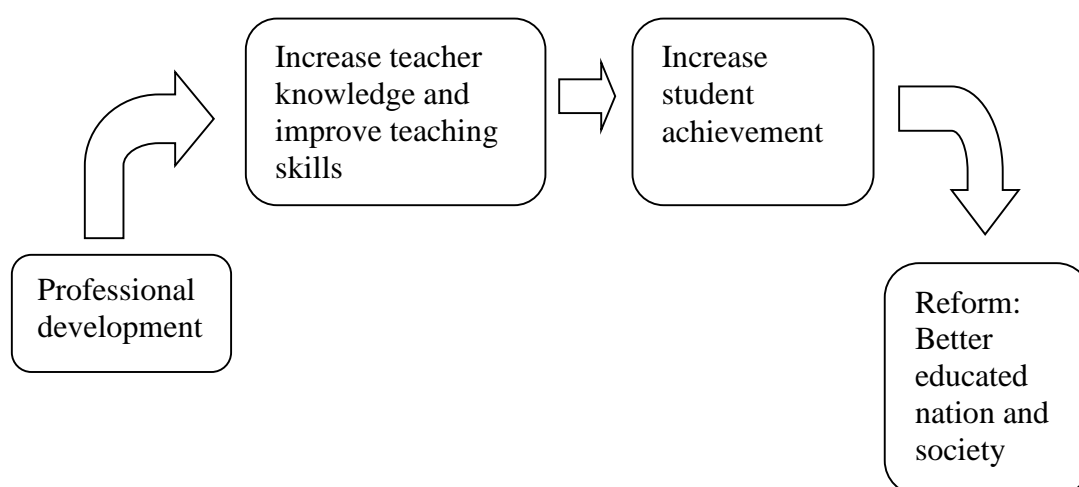


Figure 2. How professional development yields reform

In their first report on research study of professional learning opportunities in the USA and abroad, Darling-Hammond, Wei, Andree, Richardson, and Orphanos (2009) found that opportunities for sustained, collegial professional development which changes in teaching practice and student achievement were more prevalent in most of the high-achieving nations than USA. In a similar report, teachers in high-achieving Organization for Economic and Co-operative Development (OECD) nations are reported as having more time in their regular work schedules for cooperative work with colleagues (Wei, Darling-Hammond, & Adamson, 2010). The authors noted however, that, progress has been made as many states in the USA now provide induction support to beginning teachers and professional development for science and mathematics teachers on content and pedagogical skills for the subjects they teach.

Designing Professional Development for Teachers

Evidence from research shows that effective professional development programmes designed for teachers correlate positively with student learning and achievement. Mizell (2010) describes effective PD as those that focus on the information and skills teachers need to address students' learning difficulties. PD should therefore cause teachers to improve their instruction. As pointed

out previously, PD that focuses on teacher subject-matter knowledge and pedagogical skills have a positive impact on student learning and achievement (Banilower et al., 2007; Blank et al., 2007; Darling-Hammond & Richardson, 2009; Garet et al., 2001). Even though PD is usually used to mean a formal process such as a conference, seminar, workshop or collaborative learning among members of a work team, it can also take place in informal contexts, such as discussions among colleagues, independent reading and research, observations of a colleague's work, and/or other learning from a peer (Mizell, 2010). Thoughtful planning and implementation is required for any PD approach to be effective.

Research has shown that the amount of PD teachers receive has a positive impact on their learning and student outcomes (Yoon, Duncan, Lee, Scarloss, & Shapley, 2007). The short-term workshops tend not to cause as great a change in teacher practice and student achievement (Banilower et al., 2007; Garet et al., 2001; Wei et al., 2010). The researchers found that PD activities that span a longer time period with a greater number of contact hours (an average of 8-14), and that require on-going reflection are more likely to bring a positive change. In view of this, Darling-Hammond and Richardson (2009) advise that schools should make PD a coherent part of their activities rather than the "traditional one-shot workshop" (p. 48). They further indicated that disparities sometimes exist between what teachers learn in professional development work and what they can in fact, put into practice in their classrooms, so to avoid this situation, professional learning opportunities must be linked with the curriculum, assessment, and standards.

A number of important factors and/or inputs underpin the design and implementation of any effective professional development. Loucks-Horsley et al. (2010) identify four key factors into the professional development design process that could help professional developers to make an informed decision. These are: knowledge and beliefs, context, critical issues and strategies. Physics is one of the subjects in which students have to master complex skills and reasoning processes that are essential for scientific literacy. In order for this vision to be realised, Loucks-

Horsley et al. (2010) emphasized that teachers need to have strong content knowledge and pedagogical skills for their subject. Thus, teachers need to have a quality education and feel competent to create appropriate learning environments for their students. For teachers to be able to do this, the authors insist that teachers need opportunities for on-going professional development, especially one in which they (teachers) can learn what they need to know and how they can work with their students to achieve that goal.

Timperley (2011) observes that teacher professional development, which is quite often seen as a solution for improving schools and raising achievement, rarely lives up to expectations. Timperley therefore calls for a shift from professional development to professional learning which is capable of promoting teacher and student engagement, learning and well-being. This type of professional learning is inquiry in nature and teachers take control of their own professional learning through reflection of their own teaching practices (Timperley, 2011).

What Professional Development do Physics Teachers Need?

Professional development is viewed in this study from the point of view of Scheerens (2009) as the body of systematic activities to prepare teachers for their job, including initial training, induction courses, in-service training, and continuous professional development within school settings. The most frequently used analytical variables when attempting to explain why some teachers are more effective than others are mastery of subject matter and pedagogical knowledge. Additional components sometimes included in the concept are knowledge of the appropriate use of teaching materials and media, as well as strategic knowledge about the application of teaching strategies (Geijsel, Slegers, Stoel, & Krüger, 2009; Krauss et al., 2008; Scheerens, 2009). Krauss et al. (2008) define three main components of pedagogical content knowledge: knowledge of tasks, knowledge of students' prior knowledge and knowledge of instructional methods. These authors measured pedagogical content knowledge by means of an assessment centre type of approach, in which teachers rated real-life teaching scenarios in mathematics classes. Their results gave a basis

for the hypothesis that teachers with more pedagogical content knowledge display a broader repertoire of teaching strategies for creating cognitively stimulating learning situations. Another interesting outcome was that, pedagogical content knowledge was highly correlated with subject matter mastery, thus suggesting that deep knowledge of the subject matter is indeed the critical precondition for pedagogical content knowledge. Even though the study was conducted in mathematics, the findings are by no means limited to mathematics alone. Physics teachers also need to have good pedagogical content knowledge and mastery of their subject matter.

It has also been stated that physics teachers should participate in a variety of professional activities within the school context to stimulate both their own professional development and the development of the school (Scheerens, 2009). Acknowledging this raises the important questions of which professional activities can improve teachers' participation in school practice and which type of teacher learning needs should be promoted. Based on the available literature and research, the following professional learning activities, which are crucial for enabling teachers to deal with the rapid changes they face, can be distinguished: keeping up to date (collecting new knowledge and information), experimentation, reflective practice (giving and asking for feedback), knowledge sharing and innovation (Geijssel et al., 2009; Janssen & Van Yperen, 2004; Krauss et al., 2008; Kwakman, 2003; Scheerens, 2009). Research findings have also shown that teacher collaboration aimed at improving instruction and education is also quite relevant (Meirink, 2007). Co-operative and friendly collegial relationships, open communication, and the free exchange of ideas may also be sources of emotional and psychological support for teachers of physics in promoting their professional development (Toole & Louis, 2002).

Furthermore, research has shown that teachers' participation in decision making, which supports an 'organic' form of school organization, has positive effects on teachers' motivation and commitment to change (Geijssel et al., 2009; Jongmans, Slegers, Biemans, & De Jong, 2004). Learning is maximized if school staff, and teachers in particular, are provided with information on

important school issues such as developments in student performance or the extent of parental participation. (Earl & Katz, 2006; Leithwood, Aitken, & Jantzi, 2006). Even though there are indications that schools with these characteristics do indeed promote educational change and enhance student learning, it is necessary to find more thorough and strong evidence for the claim that continuous professional development in schools can sustain teacher improvement and development and thereby enhance student learning.

The Teaching and Learning International Survey (TALIS) 2013 results highlight that teachers' roles today have changed and their current knowledge and skills may not match new needs and expectations (OECD, 2014). The OECD (2014) stressed that teachers provide the most important influence on student learning, yet, teachers are often not developing the practices and skills necessary to meet the diverse needs of today's learners. The TALIS results emphasize the importance of collaborative professional learning between teachers, since those teachers who participate in collaborative professional learning activities reported being significantly more confident in their abilities (OECD, 2014). The OECD (2014) report added that if teachers are now expected to prepare students to become lifelong learners, they themselves need to learn and develop throughout their career.

Purposes and Practices of Assessment in Teaching and Learning

Formative and Summative Assessments

Assessment in education is the process of measuring a student's mastery of knowledge and skills to make an informed decision about the student (Black & Wiliam, 1998). Teaching, learning and assessment are completely inextricable (Shepardson & Britsch, 2001) in the classroom and they ought to be understood as interactive and cyclical (Darling-Hammond & Baratz-Snowden, 2005). Even though the general purpose of teaching is to enable learning, assessment has several purposes, including monitoring students' progress; diagnosing students understanding, abilities and difficulties; informing teaching; reporting to parents on their children's achievement; providing constructive feedback to learners; informing pedagogy and thereby improving the

quality of teaching and subsequent learning (Atkin, Black, & Coffey, 2001; Darling-Hammond & Baratz-Snowden, 2005; Moreland & Jones, 2000; Shepardson & Britsch, 2001).

The purposes of assessment may also fall into three broad areas. These are those concerned with “support of learning, reporting the achievement of individuals and satisfying demands of public accountability” (Black, 1998, p. 24). Therefore, one has to choose, with care, the methods of assessment that will match the intended purposes (Hackling et al., 2001). Assessment in the classroom may be formative, or summative. Formative assessment is diagnostic in nature (Black, 1998) since it is intended to provide the teacher and learner with feedback about teaching and learning processes. The results from formative assessment inform the teacher about students’ performance abilities in the teaching and learning process and the teacher uses the information to reform his/her teaching (Atkin et al., 2001; Conner, 2013; Shepardson & Britsch, 2001). The practice of formative assessment must therefore be integrated into teaching and learning since it is essential to quality teaching (Black, 1998; Darling-Hammond & Baratz-Snowden, 2005)

Summative assessment, on the other hand, refers to the cumulative type of assessment which normally occurs in large-scale testing (Atkin et al., 2001) to make a judgement about students’ achievement at specific points in time. Specifically, summative types of assessment provide information for certification, qualifications, placement promotion and accountability purposes (Atkin et al., 2001; Black, 1998; Black & Wiliam, 1998). Whereas formative assessment involves participation and a close relationship between teacher and learners (Hackling et al., 2001) the primary role and responsibilities with respect to summative assessment fall on the teacher and the external tests (Atkin et al., 2001). The differences between formative and summative assessments in terms of purposes, role and responsibilities are summarised in Table 1 below.

Table 1: Purposes, Roles and Responsibilities of Assessment

Type	Purpose	Roles and responsibilities
Formative	Identify students difficulties and capabilities Improve learning Inform instruction	Student and teacher
Summative	Certification Placement Promotion Accountability	Teachers and external tests

Approaches to Classroom Assessment

Essential to classroom assessment is the need for the assessment to reflect the nature of the teaching and learning activities. Research on classroom assessment has shown that regular and high-quality assessment can impact positively on students' achievement (Atkin et al., 2001). Darling-Hammond and Baratz-Snowden (2005) argue that formative assessment can be a “powerful tool in targeting instruction so as to move learning forward, therefore, beginning teachers must be knowledgeable about formative assessment so that it is carried out during instructional processes for the purpose of improving teaching or learning” (p. 23). Classroom assessment practices most often requires the use of multiple assessment sources (Shepardson & Britsch, 2001) so teachers ought to be skillful at using various strategies and tools.

The types of assessment tools used in the classroom may include practical tasks, written test/work, quizzes and oral reports (Hackling et al., 2001; Shepardson & Britsch, 2001). Observations of students' performance, student interviews, discussions and responses on tests are other assessment strategies that can be employed in the classroom (Atkin et al., 2001; Darling-Hammond & Baratz-Snowden, 2005). These approaches are capable of generating information that can be used to provide feedback to the teacher and/or the students on teaching and learning processes. The information can provide effective assessment to improve learning and teaching.

The *NZC* emphasizes that the primary purpose of assessment is to improve students' learning and tasks schools with keeping assessment to levels that are manageable and reasonable for both students and teachers. In order to achieve this goal, the *NZC* has categorically stated that "not all aspects of the curriculum should be formally assessed, and excessive high-stakes assessment in years 11-13 is to be avoided" (Ministry of Education, 2007, p. 41).

Summary

This review explored both theoretical and empirical perspectives of the literature related to the research topic. The theoretical perspectives covered two areas namely; constructivism theory and the cognitive apprenticeship model. These two provide teachers with an understanding of how learning occurs and therefore involve their students in the teaching and learning processes, and students are able to solve their own problems.

Research has shown that for physics education in particular, the motivation, active knowledge and participation of the students is of paramount importance. Passive, unmotivated students, a template of pattern solving principles and minimal creativity learning have little future in contemporary education (Ülen & Gerlič, 2012). At the heart of physics education research is exploring how a shift in physics instruction from concentrating on teaching to focussing on students' learning improves outcomes. In order to make this shift achievable, Redish and Steinberg (1999) stressed that teachers of physics need to listen to students about what they (students) are thinking helps them to learn. By doing this, teachers begin to make sense of how students learn physics in a way that helps them to meaningfully improve their courses.

The advances in computer hardware and software have provided new platforms for instigating conceptual change and problem solving. Applets have been running on the World Wide Web for the past decade. A similar model, which has been developed, tried and tested, to help develop students' conceptual understanding and problem solving is Physics Education Technology (PhET) (Wieman et al., 2008). PhET simulations are web-based interactive tools for teaching and learning physics. Greater use of such software in teacher preparation programmes might assist new teachers

to become familiar with and actively incorporate digital objects for demonstrations and for students to use to gain understanding and to solve physics problems.

The use of interactive engagement methods, in teaching and learning of physics, is another significant change in the teaching methodology. Examples of interactive engagement methods that have been discussed in this review are peer instruction (Mazur, 1997), interactive lecture demonstration (Sokoloff et al., 2007; Sokoloff & Thornton, 1997), photonics explorer (Prasad et al., 2012), and augmented reality (Dünser, Walker, Horner, & Bentall, 2012)

Over the years preparation of physics teachers has been a purposeful intellectual endeavour by many countries, institutions and universities. The report by the American Association for Employment in Education (AAEE) indicates that physics teaching positions are the most difficult to fill in high schools (McLeskey et al., 2004). It also encourages universities to initiate proactive programs to train more physics teachers for high schools (Etkina, 2010).

For effective physics education to occur, students have to actively work to make sense of the concepts for themselves. The information cannot simply be transferred from the teacher to the students. To better understand what could be done to improve physics education in New Zealand specifically, there is the need to undertake not only an attitudinal study, as a great deal of work has already been done with survey research (Blickenstaff, 2010), but also more in-depth study through observations, interviews and documentary analysis to examine students' encounters with physics in different high school settings. This diversity of settings will enable the researcher to examine and identify issues of commonalities which may in turn improve practice and inform policy decisions.

CHAPTER 3

METHODOLOGY

This chapter provides a detailed description of the design, instruments and procedures that were used to gain insights into the state of teaching and learning of physics in New Zealand secondary schools. The section is therefore organized under the following sub-headings: research design, population, sample and sampling technique, instruments for data collection, method of data collection and method of data analysis.

Research Design

In this study, an attempt was made to investigate and describe the policies and practices in New Zealand physics education by looking at initial teacher education programmes, the current state of physics teaching and learning in secondary schools and what supports physics teachers to be successful. The study therefore followed a mixed method design using both survey and case study techniques. Specifically, the *convergent parallel design* (Creswell & Clark, 2011) was employed for this study. The design involved two stages in which mixed methods were used to collect data. The framework for the design is shown below.

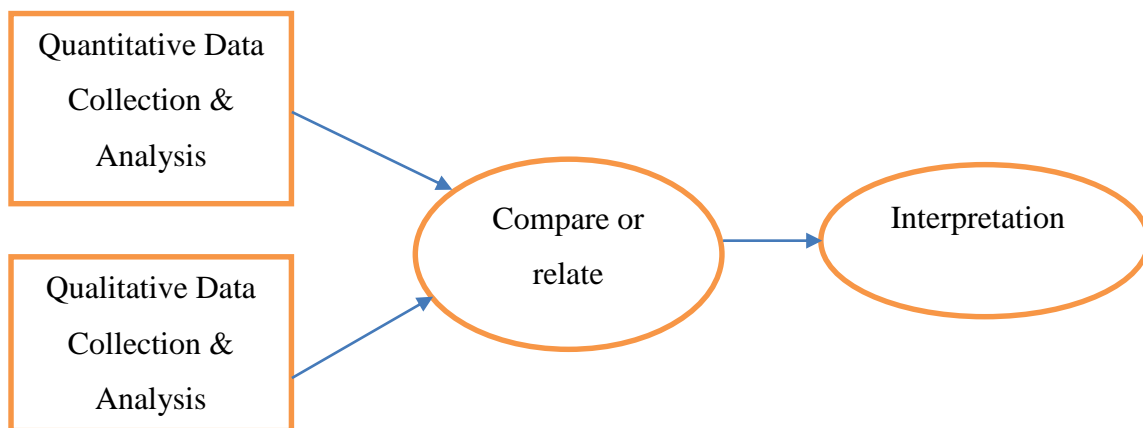


Figure 3. The convergent parallel framework

Description of the Design

The convergent parallel design (also called convergent design) involves the use of concurrent quantitative and qualitative data collection, separate quantitative and qualitative analysis and the merging of the two data sets (Creswell & Clark, 2011). It has been observed that if a study uses different research methods, for example quantitative and qualitative, it has the advantage of helping the researcher to gain a deeper understanding of certain issues pertaining to the problem under investigation (Best & Kahn, 2005; Cohen, Manion, & Morrison, 2007; Taylor, 2004). The use of multiple data sources and cross comparisons to gain understanding of a phenomenon ensures trustworthiness and credibility of interpretation of data collected (Creswell, 2007).

A survey method was used in the first stage in which questionnaires were administered to physics teachers throughout New Zealand and physics students of some selected secondary schools in Christchurch. The teachers' survey was intended to identify their views of initial teacher education, typical practices in curriculum delivery, their perceptions of the factors limiting the quality of physics teaching and learning and ways to improve upon the situation, if any. The students' survey was designed to gather students' views about their interest in physics, curriculum implementation, their own competencies and challenges, and what would motivate them to be trained as physics teachers.

The second stage of this study was designed to examine the realities of the matter under investigation in more detail to provide depth of information through specific case studies. This part of the study was meant to move beyond the perception based data (Creswell, 2007). The operational word here is "describe", that is, describing as accurately as possible the phenomena that is the subject of this study, refraining from any pre-given framework and remaining true to the facts (Groenewald, 2004). I was concerned with the lived experiences (Cohen et al., 2007) of physics teachers and students who are involved in the issue under study; hence a case study method was adopted for this second stage. Heitzmann (2008) asserts that the case study method provides "many opportunities and strategies to gain insight into events that occur within the school and classroom" (p. 523). Bogdan and Biklen (2007) assert that a case study is useful for inquiry which

entails “detailed examination of one setting, or a single subject, a single depository of documents, or a particular event” (p. 59). Creswell (2007) however, views a case study as both a methodology and a product of inquiry in which the researcher investigates one or multiple cases “over time through detailed, in-depth data collection involving multiple sources of information” (p. 73). Yin (2009) also defined a case study as an “empirical inquiry that investigates a contemporary phenomenon in depth and within its real-life context” (p. 18). The embedded multiple-case study design (Gray, 2009; Yin, 2009) was specifically adopted for the second stage. Multiple-case designs make it possible to replicate a case under review in one study. Moreover, independent conclusions arising from two or more cases are more trustworthy than those from a single case (Yin, 2009).

The second stage was however, carried out in two phases. Phase one involved collection of quantitative data from students and classroom observations. As noted by Cohen et al., (2007), observation enables the researcher to understand the situation being described, see things that might otherwise be unconsciously missed in the first stage and discover things that respondents might not freely talk about in the questionnaire and interview situations. Observation also provides specific examples of teaching and learning in action. Cohen et al. extolled that observations enable the researcher to gather data on: “physical settings (e.g. the physical environment and its organization); the interactional setting (e.g. the interactions that are taking place, formal, informal, planned, verbal, non-verbal etc.); and the programme setting (e.g. the resources, pedagogy styles, curricula and their organization)” (p. 397).

Phase two of the second stage involved focus group interviews with physics students and individual interviews with high school physics teachers and physics teacher educators. The purpose of this was to investigate qualitatively, and delve deeper into issues that were not possible to obtain from questionnaires (Fraenkel, Wallen, & Hyun, 2012). Also, interviews were conducted with other stakeholders who have an influence on science education in New Zealand. The stakeholders’ interviews were intended to obtain a national perspective as far as the study is

concerned. It was also designed to obtain direct information about their experiences, knowledge and opinions about teaching and learning of physics in secondary schools.

Rationale for the Design

The study first of all sought to investigate and describe the state of teaching and learning of physics in secondary schools in New Zealand. That is, to identify typical practices in curriculum implementation, factors limiting quality teaching and learning, and ways to improve upon the situation. Again, the study sought to gather students' views about their interest in physics, their own competence and work attitude to physics. To do this, it is practically sensible to gather data from a population of physics teachers and physics students, physics educators, and also delve deeper into the data obtained in order to adequately, describe the state of the matter under investigation. To meet this expectation, survey and case study methods were found as most appropriate for the study. They were capable of providing a more complete understanding of the topic under investigation through validation and corroboration of findings from the quantitative and qualitative measures (Creswell & Clark, 2011).

In choosing one method or the other for research work, Burgess (1984) argues that one should be guided by two main things: the kinds of information relevant to the problem of interest to the researcher and the kinds of methods relevant for the topic under investigation. Burgess discusses that there is no best method for conducting educational research and that the method one chooses and uses should be suited to the issue or topic being explored. Likewise, Vulliamy, Lewin, and Stephens (1990) have indicated that the approach to social research does not stem from fundamental philosophical commitments only. Thus, other significant considerations, such as the particular purposes of the research and the practicality of various strategies given the circumstances in which the inquiry is to be carried out, must be taken into account, i.e. context in which the observations are made is important. The survey was used in this study because surveys are useful for gathering factual information, data on attitudes and preferences, beliefs and predictions, behaviour and experiences – both present and past from a wide range of participants to ascertain more general perceptions and behaviours (Cohen et al., 2007; Fraenkel et al., 2012;

Sarantakos, 2005). Fraenkel et al. (2012), for example, noted that surveys have the potential to provide a lot of useful information from the subjects of the study. Nworgu (2006) also noted that surveys make it possible for many subjects to be studied at one time.

In actual fact, no single approach, either survey or case study methods, can be perfectly effective (Burgess, 1984; Vulliamy et al., 1990) and therefore each method can be improved significantly through triangulation of data from various sources (Bogdan & Biklen, 2007; Gray, 2009; Keser et al., 2010; Yin, 2009). Data from many sources can contribute multiple views better in a study than single sources (Bogdan & Biklen, 2007; Yin, 2009) because multiple sources lead to a fuller understanding from different perspectives of the topic under investigation (Keser et al., 2010). Gray (2009) also noted that “people may articulate a particular view, but in practice behave differently” (p. 221). Keser et al. (2010) further uphold that data collected from a survey should be used as a springboard for further data collection using different research methods, including interviews and classroom observations.

Keser et al., (2010) emphasized that triangulation helps researchers to “secure an in-depth understanding of the learning environment” (p. 7). Case studies therefore allow for in-depth research of particular teachers and situations, produce first-hand information, and allow employment of a variety of methods and sources for triangulation to see how well what teachers say they do matches what they actually or are observed to do (Sarantakos, 2005). Case studies are also useful for researching contemporary events in which direct observations of events as well as interviews of people in real life contexts to yield deeper understanding of a phenomenon (Cohen et al., 2007; Sarantakos, 2005, Yin, 2009). These approaches (survey and case study) and the methods outlined above were relevant to this study in that they helped me to triangulate and corroborate findings from teachers, students, documents and stakeholders in order to describe thoroughly the topic under investigation.

Potential Limitations

The survey and case study approaches, for this study, presented above have the advantage of describing thoroughly how physics is taught in the secondary schools for specific teachers and situations. However, there is no method that is free of problems (Sarantakos, 2005) and there are inherent challenges which I have tried to address (refer to the section on limitations, Chapter 7). First of all, survey questionnaires are difficult to construct and secondly, the success of using questionnaires lies in getting respondents to answer questions thoughtfully and honestly (Fraenkel et al., 2012). Another significant drawback is the time and effort of delivering and collecting the questionnaires and getting sufficient numbers of participants to respond (Gray, 2009). The main drawback of the case study method is that the subjectivity of respondents, their opinions, attitudes and perspectives together contribute to a degree of bias (Ampiah, 2004; Creswell, 2007). More so, results are also related to the unit of analysis and do not allow “inductive generalisation” (Sarantakos, 2005, p. 216). In this study, the case study was used to substantiate and expand the findings from the quantitative measures. Though case study findings were not meant to be generalized, they serve as indicators of what might be happening in other places.

Addressing the Issue of Credibility and Trustworthiness

Lincoln and Guba (1985) have explained that credibility and trustworthiness in research are established through data collection, analysis and reporting. The authors have proposed four constructs – credibility, transferability, dependability and conformability, which should be considered by researchers in pursuit of a trustworthy study. The constructs have been considered extensively by Shenton (2004) who suggested provisions and strategies that researchers may want to employ to meet the demands of their studies. There are different strategies to ensure credibility (Creswell, 2007; Fraenkel et al., 2012; Hackling et al., 2001; Sarantakos, 2005; Shenton, 2004; Yin, 2009), however, (Creswell, 2007) has recommended the use of at least two of those

approaches in any research in order to ensure credibility and trustworthiness. In this research credibility and trustworthiness were ensured by:

1. Making available to the interviewee (teacher educators, physics teachers and stakeholders) focus questions prior to the interview (Hackling et al., 2001).
2. Using member checking to obtain feedback from the participants regarding the accuracy of the information recorded (Fraenkel et al., 2012; Sarantakos, 2005).
3. Using multiple data sources (data triangulation) to gain more insight into the phenomenon under study (Creswell, 2007; Lincoln & Guba, 1985; Yin, 2009).
4. Using detailed description to report the research findings and giving voice to the research participants (Creswell, 2007; Lincoln & Guba, 1985; Shenton, 2004).
5. Providing accurate information of the phenomenon under observation and detailed description of the context of the study (Shenton, 2004).

Population

All secondary schools in New Zealand had the chance to participate in the study. The population for the study comprised senior physics teachers and Year 12 and 13 students who sit for the NCEA at levels 2 and 3. Physics is taught as a subject at Year 12 and 13 (New Zealand Qualifications Authority[NZQA], 2012a, 2012b) and as far as the purpose of the study is concerned, students from these year groups formed a better population for the study. The students normally take a broad range of courses in Year 11 that may lead them to more specialised subjects (NZQA, 2012b). In years 12 and 13, the students start thinking about what areas to focus on for future study or careers. Therefore, it was appropriate to find out from these students whether they would like to take further studies in physics and/or become physics teachers or not and their reasons for doing so. Stakeholders of physics education, i.e. initial teacher educators and secondary science coordinators also formed part of the population for the study.

Sample and Sampling Technique

The sample size for the study comprised both physics teachers and students of New Zealand secondary schools and stakeholders of education. Secondary physics teachers were invited to participate in the study by completing an online survey. The survey was first introduced to the physics teachers who attended the New Zealand Institute of Physics (NZIP) 2013 conference at Nelson in September 2013. The NZIP physics teachers' mailing list was also used to send an email (and the link to the survey) to all secondary physics teachers, presumably to those who are members of NZIP, and websites for two professional teacher organisations; the New Zealand Association of Science Educators (NZASE) and the Canterbury Science Teachers Association (CSTA), requesting them to participate in the study by completing the online survey. This was done to reach out to all the physics teachers who were not at the conference. No information about the total number of physics teachers in New Zealand was available. However, a total of 138 physics teachers started the survey and 104 completed it, representing a completion rate of 75.4%.

The participant teachers in this study had a wide variety of educational backgrounds and experiences. Their educational qualifications ranged from BSc to PhD for both teachers who participated through the online survey and the teachers in the case studies. All participant teachers had a diploma in teaching and learning or Post Graduate Diploma in Education, a requirement to teach in New Zealand. The age of the teachers ranges from 21 – 50+ years, with teaching experience averaging from 17 – 30 years. About 70% of all the teachers were less than 50 years of age. This gives an indication that New Zealand physics teachers are generally middle aged.

The student population for the study came from the schools that were selected for the case studies. The NZQA's school decile band classification – decile 1-3, 4-7 and 8-10 (NZQA, 2012a), was used as a guide to select schools for the case studies. Three state high schools from Christchurch, one school from each decile band, were purposefully sampled as a convenience sample for on-going observation (Creswell, 2007) and used as case studies. Reasons for selecting these schools included easy accessibility and willingness of school leaders and staff to engage

with the researcher. Physics teachers of these schools were interviewed and observed while teaching physics.

One private (fully independent) co-educational school, was purposefully selected as an additional and alternative case study. The physics teacher at this school was a biologist who taught biology for many years but switched to physics and had been teaching physics since then.

The sample size for the students' population was guided by the table for estimating sample size from a given population developed by Krejcie and Morgan, as cited in Sarantakos (2005, p. 173). Based on the students' population from the selected schools, respondents (students) from these selected schools were invited to participate. A total number of 97 physics students started the online survey, and of these, 85 completed the survey, representing an 87.6% completion rate. Fourteen focus group interviews were also conducted with a total of 82 students.

Purposeful sampling technique was also employed to select three teacher educators of physics who participated in the study. The reason for selecting these physics teacher educators was mainly due to their interest in the study and their willingness to participate.

Instruments

The research instruments used for data collection for this study were: survey questionnaires for teachers and students, interview protocols, classroom observational guides and situational analysis of documents, including units and lesson plans.

Survey Questionnaire

Two forms of both closed and open-ended questionnaires were developed and used for data collection. These were the Physics Teachers' Questionnaire (PTQ) and Physics Students' Questionnaire (PSQ). It has been noted that closed and open-ended questionnaires are useful to elicit both quantitative and qualitative data (Best & Kahn, 2005; Fraenkel et al., 2012). Also, many people's opinions can be elicited through questionnaires and participants can respond in a place and time convenient to them (Gray, 2009). Both the PTQ and PSQ were adapted from existing

surveys for evaluating secondary schools science and mathematics classrooms (Angell et al., 2004; Hackling et al., 2001; Ogunmade, 2005; Weiss et al., 2001). The items selected were modified to suit the purpose and context of this study. Particular attention ensured that the items constructed were unambiguous, unbiased, unloaded and relevant (Fraenkel et al., 2012; May, 2001; Sarantakos, 2005), and also appropriate for the culture and context of New Zealand. Both the PTQ and PSQ were structured into sections to reflect the research questions.

Interview Protocols

Semi-structured interview protocols were designed for physics teachers, students, and physics teacher educators. The semi-structured interview is suitable for probing views and opinions and permits respondents to develop and expand on their own responses (Gray, 2009). The semi-structured interview protocols were designed to gather data in the participants' own words (Fraenkel et al., 2012) so that greater insight could be gained about the teaching and learning of senior physics. The semi-structured method of interviewing allows the interviewer to have more opportunities to probe beyond the answers. As May (2001) noted: "the interviewer can seek both clarification and elaboration on the answers given and thus enter into a dialogue with the interviewee" (p. 123). The semi-structured method also allows the researcher to raise issues of particular concern to the study (Fraenkel et al., 2012). Further questions, which were not expected at the commencement of the interview, could be also be asked as new issues arose (Gray, 2009).

Items on the interview guides were centred on the main research question formulated to guide the study. Gray (2009) and Cohen et al. (2007) advise that the issue of validity for both structured and semi-structured interviews is addressed by ensuring that questions are related to the research objectives. The semi-structured interview protocols developed for the teachers, students and teachers educators are provided in Appendices E, F and G respectively. In order to achieve rich and constructive discussions, the interviewees (especially the teachers and the teacher educators)

were provided with the focus questions to afford them the opportunity to think about their responses before the commencement of the interviews, as Hackling et al (2001) advise.

Classroom Observational Guide

A Classroom Observational Guide (COG) was developed to measure physics classroom practices, including teacher preparedness in terms of both content and pedagogy, among many others. The COG was adapted from the five scales of Reformed Teaching Observation Protocol (RTOP) manual (Piburn et al., 2000). The RTOP has been found to be a useful checklist to constructively critique details of classroom practices, including interactive engagements, inquiry-based learning as well as teacher pedagogical content knowledge (MacIsaac & Falconer, 2002; Wyckoff, 2001). The scales that were used in developing the COG were Lesson Design and Implementation, Content Knowledge, Procedural Knowledge and Classroom Culture. Classroom Culture was sub-divided into two sections – Communicative Instructions, and Student-Teacher Relationships.

The five sub-scales for the RTOP included 25 observable items scored from 0-4 as follows: 0 (the behaviour never occurred); 1 (the behaviour occurred at least once); 2 (occurred more than once, very loosely describes the lesson); 3 (a frequent behaviour or fairly descriptive of the lesson); and 4 (pervasive or extremely descriptive of the lesson) (Piburn et al., 2000). Any RTOP score greater than 50 indicates a considerable presence of good teaching in a lesson (MacIsaac & Falconer, 2002). Due to the subjective nature of the scoring (MacIsaac & Falconer, 2002; Piburn et al., 2000), the teachers observed also completed a self-reflection checklist (see Appendix H) for each lesson observed while the researcher completed a similar checklist. The teachers' scores were matched with the researcher's scores and any differences were reconciled. The teachers expressed preference not to have more than one observer in the classroom as they felt this could alter the dynamics of the lesson.

Validity and Reliability of Instruments

The instruments were developed with the assistance of my two supervisors. The survey questionnaires, COG and interview guides were made available to experts (reviewers) in the field, including science advisors at UC Education Plus, for their comments and suggestions. The comments and suggestions from these reviewers were used to revise the initial items. The instruments were further scrutinized by my supervisors. These actions were to ensure that the items and their wording were appropriate for the participants concerned and that the information that would be obtained could be used to make sound judgements (Sarantakos, 2005) on the issues under study.

Pre-test of Survey Questionnaire

The survey questionnaires were pre-tested with a small number of physics teachers and students through an online survey hosted by qualtrics.com. Qualtrics is an online survey generation, delivery, and analysis tool (Benton, Pappas, & Pappas, 2011). The teachers' survey was made available to selected high school physics teachers in Christchurch. The teachers were selected with the help of the science advisors at UC Education Plus. The teachers had approximately four weeks to complete the survey, which was activated on July 30 and ended on August 31, 2013. When it closed, 21 physics teachers had started the survey and it had been completed by 17 teachers (representing 81.0%). The four incomplete responses were removed from the pre-test reliability analysis.

The teachers' questionnaire consisted of four different scales, making it multidimensional in nature. The scales were initial teacher education, professional development, classroom practices, and factors constraining the quality physics teaching and learning. Each scale was made up of a different number of items which were responded to on a five-point scale with extreme alternatives of Strongly Disagree-Strongly Agree, Not Important-Very Important and Never-Always. The reliability of each scale was therefore determined to find out the internal consistency of the scales,

that is, the extent to which the items that constitute the scale “hang together” (Pallant, 2007, p. 85). This was done using the Cronbach alpha reliability coefficient. The teachers’ experiences for initial teacher education had a coefficient alpha of 0.839; professional development 0.870; classroom practice 0.727 and constraining factors 0.796.

The trial of the students’ survey, was started by 44 students and completed by 38 of them, representing an 86% response rate, at the time the survey was closed. Students had two weeks, from September 5-19, 2013, to complete the survey. The six incomplete responses were removed from the pre-test reliability analysis. The students’ survey was also multidimensional in nature as it consisted of three primary scales – interest in physics topics (as indicated in the achievement standards), classroom practices and constraining factors. The classroom practices however, consisted of three subscales including teaching approaches, teacher feedback and guidance, and ICT usage. The response also used a five-point scale similar to the teachers’ survey and a Cronbach alpha reliability coefficient was computed for each scale. Coefficient alpha values of 0.861 and 0.794 were obtained for interest in physics topics and constraining factors respectively. On classroom practices, teaching approaches had a coefficient alpha of 0.747 and coefficient alpha of 0.757 and 0.830 were obtained for teacher feedback and guidance, and ICT usage respectively.

Reliability coefficients are measured by using a scale from 0.00 (very unreliable) to 1.00 (perfectly reliable) (Gray, 2009). Henderson, Fisher, and Fraser (1998) indicated that alpha coefficient values ranging from 0.62 to 0.77 and exceeding the threshold of 0.60 are acceptable reliabilities for research purposes. The responses to the open-ended items indicated that the wording of the items was appropriate to the participants concerned. The scales generated for the surveys in this research were therefore considered reliable for the study. The final PTQ and PSQ were then constructed and labelled, for the thesis, as Appendix C and D respectively.

Validation of Interviews

First and foremost, care was taken to ensure that items on the interview guide were directly related to the purpose of the research (Cohen et al., 2007; Gray, 2009). In addition, a “member checking” (Fraenkel et al., 2012, p. 458) process was used to validate all interviews. Member checking is a process whereby respondents/interviewees are asked to verify the accuracy of the research report (Fraenkel et al., 2012). In this study, all interviews were audio recorded and transcribed. After the recordings were transcribed, a copy of the transcript was forwarded to the respondents and they were requested to verify the accuracy of the information. Respondents were also asked to modify, revise and/or amend the transcript if and as necessary before any part of the transcript was used in the study.

Data Collection Procedure

Collection of data for the study was done in three stages – administration of questionnaires to physics teachers and students, interviews and classroom observations. In addition, data were also gathered from documents as described previously.

Administration of Questionnaires

An online survey (questionnaire) was developed for the physics teachers. The survey was created using qualtrics.com tool and made available to respondents (secondary school physics teachers). Items in the online questionnaire were based on the research questions. The link to the online survey was made known to the physics teachers who attended the NZIP 2013 conference in Nelson. The survey link was also posted on three websites for the teachers to access it. These were the NZIP 2013 conference website, the CSTA and the NZASE websites respectively. In addition, the NZIP physics teachers’ mailing list was used to send an email (and the link) to all secondary school physics teachers, requesting them to participate in the study by completing the survey. The websites and the physics teachers’ mailing list were used to follow up with physics teachers who were not able to attend the conference.

Students' questionnaires were administered in the students' schools. Year 12 and 13 physics students in the case study schools were asked to complete one set of questionnaires related to the study. The link for the students to do the survey was posted on their school Moodle page.

Conducting the Interviews

Two forms of interviews were conducted: face-to-face and using Skype. The face-to-face interviews were conducted with the participants from the case study schools, teacher educators and stakeholders in Christchurch. Also, three face-to-face interviews were conducted during the NZIP 2013 conference in Nelson. The Skype interviews were organised for physics teacher educators who were outside Christchurch. The Skype platform was used because it was cost beneficial and interviews were conducted more quickly as well (Gray, 2009; Sarantakos, 2005). All the interviews were conducted at dates and times convenient to the respondents. Respondents in the face-to-face interviews selected the location for the interviews.

I started each interview with an exchange of greetings and a note of thanks for the interviewee's acceptance to participate in the study. After briefly introducing myself, I reviewed the purpose of the research and how the information was going to be used, as indicated on the interviewee's consent form. Interviewees were assured that their responses would be treated confidentially and would be used for research purposes only. All interviewees, both face-to-face and Skype, were also reminded that the interviews were being audio recorded and that they could ask for the recording to be stopped if they were not comfortable with it. Then, each interviewee was asked to introduce him/herself.

The students' focus group interviews took the form of a discussion which generated different ideas and opinions from the participants. However, not all students in these groups responded to a given question. As part of the protocol, students were prompted to mention their name before talking. It was therefore not difficult to identify, in the transcript, the individual who was talking, and this method provided easy retrieval of the themes that emerged.

In the course of the interviews (both individual and group), I listened attentively to the interviewees and probed to clarify information as and when necessary. With regard to the face-to-face interviews, eye contact was maintained with the interviewees and some non-verbal expressions such as nodding and smiling were used to acknowledge responses and to indicate interest as I made written notes (Gray, 2009). For the Skype interviews in particular, asking for clarification, occasionally reaffirming the interviewee's opinions expressed and an occasional "OK" were used to show interest and provide appropriate feedback to the interviewee. Each interview closed with an expression of appreciation to the interviewee for their time and their contribution made to the study. I rounded up by asking the interviewee about contacting him/her for additional information should the need arise.

Classroom Observation

Observation involves the "systematic viewing of peoples' actions and the recording, analysing and interpretation of their behaviour" (Gray, 2009, p. 397). Observation as a data collection tool in research enables the researcher to obtain live data from naturally occurring social situations, i.e. researchers obtain direct information on what is taking place rather than relying on secondary sources (Cohen et al., 2007). Observation also provides the researcher with first-hand information about behaviour of individuals and groups (Best & Kahn, 2005; Gray, 2009; Sarantakos, 2005). In this study, a 'non-participant observation' (Fraenkel et al., 2012; Gray, 2009) method was employed to study the subjects. In this type of observation, researchers are not directly involved in the situation they are observing, they "sit on the side-lines and watch" without participating in the activity being observed (Fraenkel et al., 2012, p. 446; Gray, 2009).

Likewise, (Cohen et al., 2007) differentiate between 'participant-as-observer' and 'observer-as-participant'. Whereas participant-as-observer (also called complete participant) participates fully in the activities of the group being observed and may/may not be known to the group, observer-as-participant is only known to the group as a researcher and does not take part in the

activities of the group being observed. After obtaining the necessary permission to carry out the observations, I took the role of observer-as-participant to observe the selected classes and their lessons.

Data Analysis

Data from teachers and students' survey questionnaires were analysed using descriptive statistical methods (including percentages, means, standard deviations and graphs where appropriate) and inferential statistics – independent samples test and multivariate analysis of variance (MANOVA).

Qualitative data gathered during interviews and observations were used to substantiate findings from the survey data. Audio recordings from the interviews were transcribed. Nvivo 10 for Windows (QSR International Pty Ltd. Version 10, 2012) was used to organize the materials by coding them into nodes which provided easy retrieval of the themes that emerged. Where quotes are used within the body of this thesis, they were chosen because they were representative of the statements of most of the respondents. The production of accurate and verbatim transcripts was integral to establishing the credibility and trustworthiness of the data. Detailed descriptions of classroom observations/practices were also recorded as a reference for indicating what actually occurred. A cross-case analysis approach (Yin, 2009), also called comparative analysis (Schwandt, 2001) was adopted for this purpose. A detailed report of the individual case studies was presented, and using comparative analysis, the similarities and differences between the cases were discussed.

As indicated previously, the embedded multiple-case study design (Yin, 2009) was chosen for the second stage of the study. The purpose of this was to determine whether similar or contrasting outcomes would be produced. Yin (2009) has stated that “analytic conclusions independently arising from two cases will be more powerful than those coming from a single case alone” (p. 61). The comparison was helpful to identify how different contexts and individual expertise affect policies and practices regarding physics teaching and learning in high schools.

Ethical Considerations

Ethical approval is a requirement for research activities undertaken at the University of Canterbury. An official request for ethical approval was made to the University's Educational Research Human Ethics Committee (ERHEC). As required by ERHEC, detailed statements about the nature of the research, how data would be collected and used, and the role of the participants were forwarded to ERHEC for its consideration and approval. The documents submitted included participant information sheets and consent forms. Participants were assured of anonymity and confidentiality of the data gathered (Appendix B). That is, all names and identifying details in any verbal, written or published reports were changed into pseudonyms. Audio-tape recordings and observation notes were also kept in a locked cupboard and were accessible to me and my supervisors. These materials would also be kept for 5 years and then destroyed.

Following the granting of ethical approval (refer to Appendix A for a copy of the ethical approval letter), access to case study schools was negotiated. Letters were sent to the school principals to seek their permission to conduct the study. Upon agreement, physics teachers and students in the schools were contacted to seek their informed consent. Information sheets and consent forms were sent to the schools and participants who confirmed their participation in the study (refer to Appendix B for copies of the information sheet and consent forms). Participants appending their signature on the consent forms were an indication of their willingness to be part of the study. In the case of the online survey, respondents were asked to read the information sheet carefully before completing the survey. It was understood that by completing the survey, they had consented to participate in the study. However, the participants had the right to withdraw from the study at any time without penalty

Summary of Research Methods

Summary of the research methods including the research questions, data collection instruments, and the statistical and qualitative methods that were employed to analyse the results are presented in Table 2 below.

Table 2: Summary of Research Methods and Instruments

Research Question	Objective	Methods	Analysis
What is emphasised in the initial education of high school physics teachers in New Zealand and why?	<p>To investigate how senior high physics teachers are educated in New Zealand.</p> <p>This was linked to the course content, course structure, program requirements and whether the tertiary level study allow pre-service teachers to become effective physics teachers on their professional job.</p>	<p>Interviews with purposefully selected physics teacher educators.</p> <p>Survey responses from physics teachers.</p>	Thematic reporting of interview responses
What are the conceptions about teaching held by New Zealand high school physics teachers and how are these conceptions reflected in their teaching practice?	To qualitatively explore physics teachers' conceptions about teaching and how these conceptions reflect the teaching practice	Interviews and classroom observation	Thematic reporting of interviews compared with observation data. Interviews were transcribed and coded into nodes using Nvivo 10 for Windows. Cross-case analysis (Yin, 2009) was used to compare the differences and similarities in the cases

How do secondary teachers and students perceive their physics classroom interactions?	<p>To find out how secondary physics teachers and students perceive their physics classroom interactions and how the interactions relate to effective learning.</p> <p>Information was sought on instructional methods, classroom interaction (teacher directedness, student centeredness), extent of coverage of curriculum materials, nature of assessment, and how this links to effective teaching and learning.</p>	<p>Data from survey questionnaires.</p> <p>Interviews with teachers and students.</p> <p>Classroom observation based on the RTOP (Piburn et al., 2000).</p>	<p>Descriptive and inferential statistics –percentages, mean, standard deviations and MANOVA.</p> <p>Thematic analysis and reporting of interview responses.</p> <p>Notes from observation field note book.</p>
What on-going professional learning do the teachers receive, if any, and how effective they are, for the teaching and learning of physics?	<p>To find out professional learning and development opportunities for physics teachers, for both those who are physics majors and those who teach physics but who do not have a degree in physics.</p> <p>Areas to look at included the types of professional development teachers have undertaken.</p>	<p>Data from survey questionnaire.</p> <p>Interviews with teachers and stakeholders.</p>	<p>Descriptive statistics using percentages, means and standard deviations.</p> <p>Interview responses were analysed and reported thematically using the method described previously.</p>

What factors, if any, do teachers and students perceive as constraining the quality teaching and learning of physics in New Zealand?	To identify factors constraining the quality teaching and learning of physics.	Data from teachers' and student' survey questionnaires. Interviews with teachers, students and stakeholders.	Descriptive and inferential statistics – frequencies, means, standard deviations and MANOVA. Thematic analysis and reporting of interviews to substantiate findings from the questionnaires.
What changes do teachers and students perceive need to occur in the teaching approaches used for senior physics in high schools in New Zealand?	To identify ways to improve the teaching and learning of high school physics. Information was also sought about experiences of teaching and learning in other subjects.	Data from teacher and student questionnaires. Interviews with teachers, students and stakeholders.	Descriptive statistics – frequencies, means and standard deviations. Thematic analysis and reporting of interview responses.

CHAPTER 4

QUANTITATIVE RESULTS

In this chapter, the findings from the survey questionnaires enquiring into the teaching and learning of physics in New Zealand secondary schools are presented in relation to the research questions that were formulated to guide the study. More specifically, this chapter examines the results from the teachers' and students' questionnaires, which were used to amass data regarding the respondents' beliefs about the teaching and learning of physics. The research questions are discussed in Chapter 6.

Analysis of Teachers' Survey Questionnaire

In the first instance, demographic data about the physics teachers was collected, including their age, gender, years of teaching experience, educational attainment, type and authority of school, course background and completion year of initial teacher education (ITE). The teachers' data is presented in the following section.

Teacher Characteristics

Demographic Data

A total of 138 physics teachers started the online survey, with 104 finishing it, representing a 75.4% completion rate. The remaining 34 (24.6%) incomplete responses were deleted and not used in the analysis. The distribution of the teachers' biographical data is presented in Table 3. As seen in Table 3, the majority of the physics teachers who participated in the study were males (67.3%). Females constituted about 33% of the teachers surveyed. Approximately 60% of all respondents were above 40 years of age and about 57% of the teachers had been teaching physics for more than 10 years.

Table 3: Characteristics of Physics Teachers (N = 104)

Characteristic		Frequency	Percentage
Gender	Male	70	67.3
	Female	34	32.7
Age (in years)	21-30	11	10.6
	31-40	32	30.8
	41-50	31	29.8
	51+	30	28.8
Teaching experience	< 1 year	3	2.9
	1-2 years	9	8.7
	3-5 years	17	16.3
	6-10 years	16	15.4
	11-15 years	20	19.2
	16+	39	37.5
Educational attainment	PhD	5	4.8
	Masters	22	21.2
	1 st Degree	76	73.1
	Others (HNC)	1	1.0
Type of school	Co-educational	77	74.0
	Girls only	19	18.3
	Boys only	8	7.7
Completing year of ITE	1965-1987	27	26.0
	1988-2000	27	26.0
	2001-2007	24	23.1
	2008+	26	25.0

Only a few teachers had less than three years' experience of physics teaching (11.6%), others had three-five years of experience (16.3%). As also seen in Table 3, about 26% of the teachers had earned degrees beyond the Bachelor's level. The majority (73.1%) had obtained their first degree in their respective science areas and had also completed a one-year post graduate diploma in Faculties of Education in universities and/or had participated in a conjoint degree programme. The teachers who participated in the study completed their ITE between 1965 and 2012.

The results in Figure 4 show that the majority of the teachers, 75 representing 72.1% received their ITE in New Zealand and about one-fourth overseas.

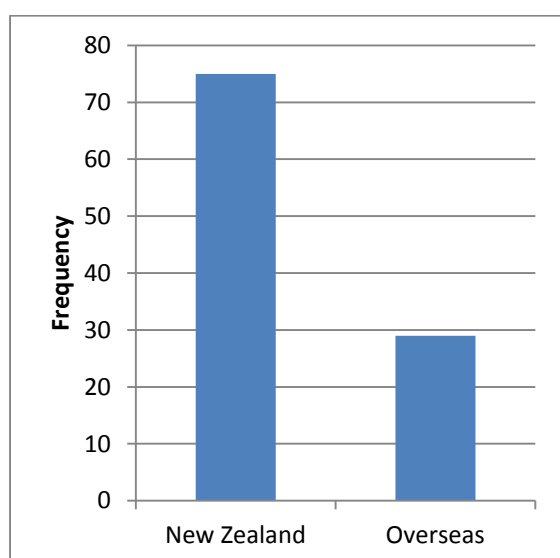


Figure 4: Country of initial teacher education

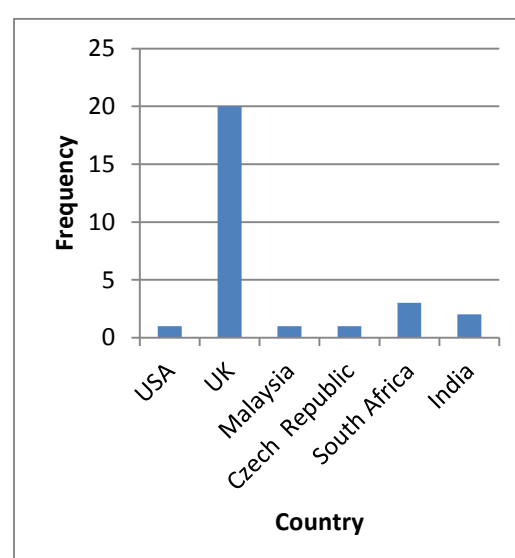


Figure 5: Distribution of teachers from overseas

The distribution of the 29 (27.9%) teachers from overseas is shown in Figure 5. Of these teachers, 20 representing 69% came from the United Kingdom.

Course Background

When asked to indicate whether physics was their primary or first-choice teaching subject, Figure 6 shows that physics was a first-choice teaching subject for about three-quarters of the

teachers. The remaining one-fourth have switched over to physics in the course of their teaching career. Their reasons for doing so were explored in this study.

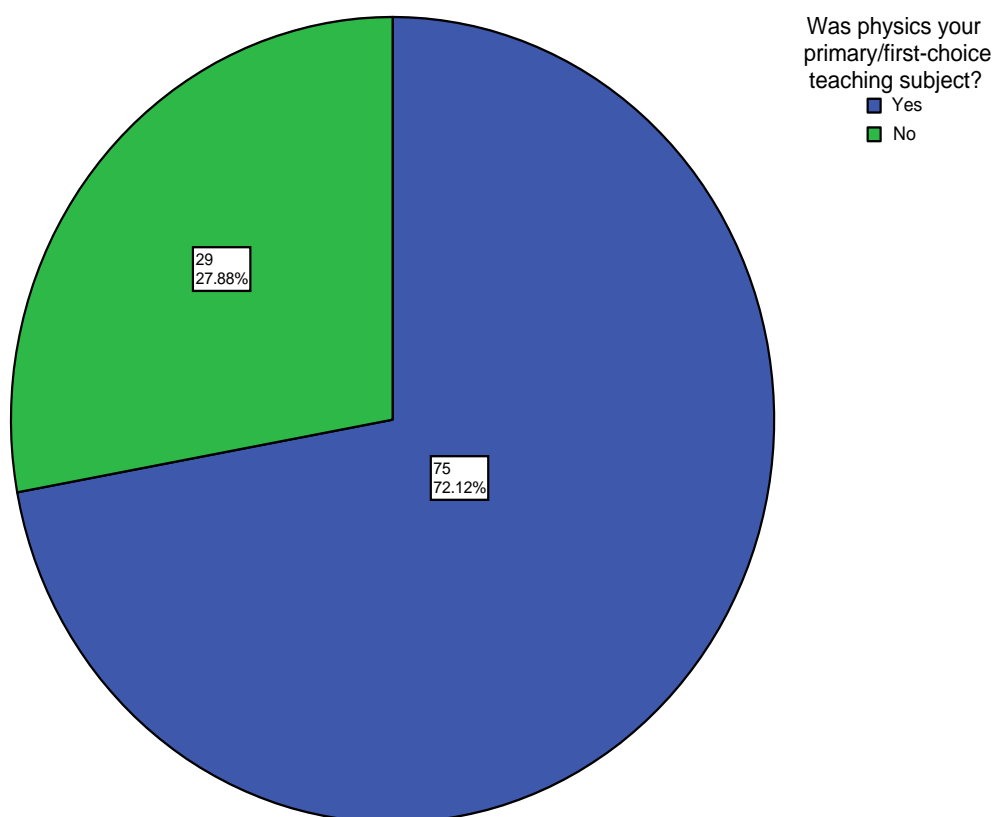


Figure 6: Physics as first choice teaching subject

The physics teachers whose first-choice teaching subject was not physics were asked to indicate their content background in physics (undergraduate course) by responding “Yes” or “No” to a list of recommended college/university physics content courses (Weiss et al., 2001). The summary of their responses is presented in Table 4.

As seen in Table 4, about 90% of the teachers whose first-choice teaching subject was not physics had completed a college/university course in Mechanics. Most had also completed course work in Introductory Physics (79.3%), Electricity and Magnetism (75.9%), Waves (72.4%) and Optics (62.1%). Electronics was an area where the majority of the teachers (69.0%) had not completed any course work on. Similar observations were recorded for Atomic and Nuclear Physics (51.7%) and Modern Physics (51.7%).

Table 4: Non-Physics First-Choice Teachers Completing Various Physics Content Courses (N = 26)

College/university physics content course completed	Yes		No	
	Freq.	%	Freq.	%
Introductory Physics	23	79.3	6	20.7
Electricity and Magnetism	22	75.9	7	24.1
Heat and Thermodynamics	20	69.0	9	31.0
Mechanics	26	89.7	3	10.3
Atomic and Nuclear Physics	14	48.3	15	51.7
Optics	18	62.1	11	37.9
Waves	21	72.4	8	27.6
Electronics	9	31.0	20	69.0
Modern/Quantum Physics	14	48.3	15	51.7

Why Teachers Became Physics Teachers

As stated previously, physics was a first-choice teaching subject for about three quarters of the teachers surveyed. An open-ended item was used to elicit the reasons why the teachers became physics teachers. The reasons why participants became physics teachers were investigated to inform how more teachers might be attracted into the profession. Reasons cited for becoming physics teachers fell into the following categories:

1. personal interest,
2. family background,
3. an encounter with an inspiring physics teacher and
4. access to a teacher scholarship scheme.

The summary of the teachers' responses is presented in Figure 7.

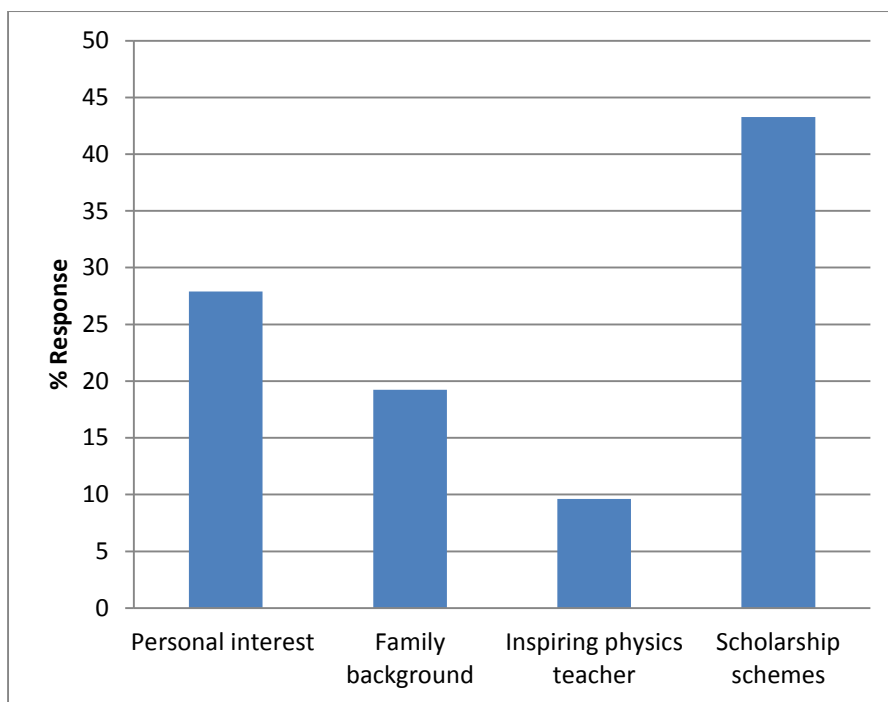


Figure 7: Reasons why teachers became physics teachers

As seen in Figure 7, the majority of the teachers (43.3%) became physics teachers through scholarship schemes that were instituted specifically for the education of physics teachers due to a shortage at that time. A financial incentive was offered to them to become physics teachers, improving upon their existing remuneration. One teacher remarked:

...and at that time they had a scheme to encourage physics graduates into teaching because there was a shortage at that time (1979), and so I was offered more money to train as a teacher than I was getting from my previous job. (Physics teacher)

About 27% of the teachers emphasized that they had always wanted to teach, and because they excelled at physics and mathematics and/or did a physics related course at university, they became physics teachers. Only a few (about 10%) remarked that a previous physics teacher was influential in their decisions to enter teaching. Most completed a one-year post graduate diploma in Education at a university or participated in a conjoint degree programme to become physics teachers.

Reasons for Switching over to Physics

Likewise, an open-ended item was used to find out the reasons why one quarter of the teachers switched to physics from another subject in the course of their teaching career. The responses/reasons given by the teachers were placed into the following categories:

1. job availability
2. lack of physics teachers and
3. interest in physics.

As can be seen from Figure 8 the main reason (about 55%) why the teachers changed to physics was a lack of physics teachers/subject specialists to teach the subject. Job availability was the next most popular reason (about 40%) mentioned by the teachers.

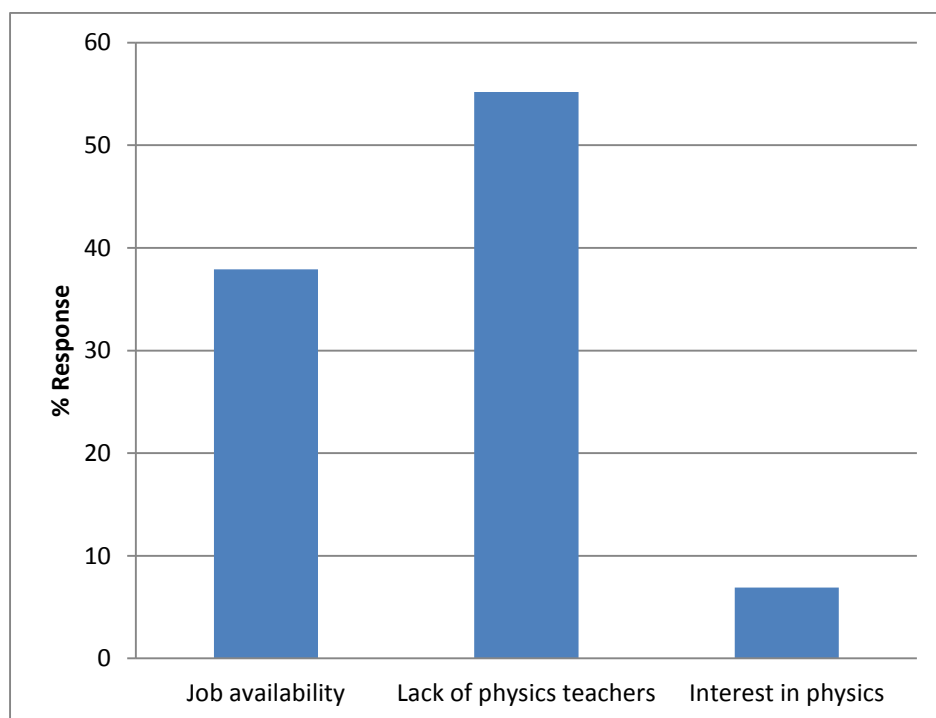


Figure 8: Teachers' reasons for switching to physics

Examples of responses offered by the teachers in relation to the categories are presented in Table

Table 5: Category and Example of Responses by Teacher who switched to Physics (N=29)

Category	Example of response
Job availability	<ul style="list-style-type: none"> - That was the job that was available in an area of NZ that I wanted to teach in. - The vacancy at the school I wanted to teach at was for physics. - Employed as a physics teacher though my background was mathematics. - Great job opportunity in NZ.
Lack of physics teachers	<ul style="list-style-type: none"> - Lack of staff to meet the needs of the curriculum. I trained in Biology but have switched to physics. - There were a lack of Physics teachers in our school when I first started, so I was encouraged to teach Physics classes starting at Y11. I really enjoy teaching Physics and therefore continue to do so. - Timetabling requirement to cover classes in present school. - No one else to do it at current school - Teacher shortage at school. - Needed a class covered so started with a Year 12 class for about 7 years, past 5 years have taught Year 13.
Interest in physics	<ul style="list-style-type: none"> - More interesting to teach. - Physics is more interesting and easier to teach than Technology as Physics is more black and white than technology when it comes to assessments.

Initial Teacher Education of High School Physics Teachers

Research question one aimed to find out what was emphasised in the training of high school physics teachers. Specifically, the question was intended to determine the course content, course structure and program requirement of physics teacher education in New Zealand. More importantly, the question sought to find out whether the tertiary study adequately prepared and allowed pre-service teachers to become effective in their job. In order to answer this question, data were obtained from initial teacher educators, and physics teachers who at the time of this study were teaching the subject at high schools across the country. In the following sections, the findings from the physics teachers are presented. Findings from the teacher educators are presented in Chapter 5.

Teachers' Perceptions of their Preparedness to Teach Physics Topics

The teachers indicated the extent to which their ITE prepared them on better approaches to teach various physics topics currently taught in NZ high schools. Their responses were coded and ranked using a scale of 1 (not sure) to 4 (very well prepared). The percentage responses and the mean scores are presented in Table 6.

Table 6: Teachers' Perception on their Level of Preparedness to Teach Various Physics Content Areas

Content areas	Frequency (and percentage) of responses (N=104)				Mean	Std. dev.
	Very well prepared	Adequately Prepared	Not well prepared	Not sure		
Mechanics	29 (27.9)	55 (52.9)	17 (16.3)	3 (2.9)	3.06	0.75
Waves	28 (26.9)	51 (49.0)	22 (21.2)	3 (2.9)	3.00	0.78
Electricity and Magnetism	30 (28.8)	49 (47.1)	22 (21.2)	3 (2.9)	3.02	0.79
Electronics	9 (8.7)	31 (29.8)	57 (54.8)	7 (6.7)	2.40	0.74
Atomic & Nuclear physics	24 (23.1)	47 (45.2)	30 (28.8)	3 (2.9)	2.88	0.79
Modern physics	19 (18.3)	37 (35.6)	45 (43.3)	3 (2.9)	2.69	0.80
Investigations	19 (18.3)	48 (46.2)	35 (33.7)	2 (1.9)	2.81	0.75
Applications	13 (12.5)	35 (33.7)	51 (49.0)	5 (4.8)	2.54	0.77

The mean scores, as can be seen in Table 6 show that the physics teachers felt more qualified and/or prepared to teach Mechanics (3.06), Electricity and Magnetism (3.02), and Waves (3.00) but considered themselves weak in Atomic and Nuclear physics (2.88), Investigations (2.81), Modern Physics (2.69), Applications (2.54), and Electronics (2.40). For all of the content areas, only a few teachers indicated that they were unsure whether their initial teacher preparation programme made them suitably qualified to teach in those areas.

An inferential statistical analysis was conducted to find out if any significant difference existed between teachers who received their ITE in New Zealand and those who trained overseas on their views about their levels of preparedness to teach physics topics. As shown in Figure 9, visual inspection of the pattern of scores for the two groups of the teachers showed a difference in the mean scores between the groups. This recorded difference was further investigated with an independent-samples t-test (Table 7).

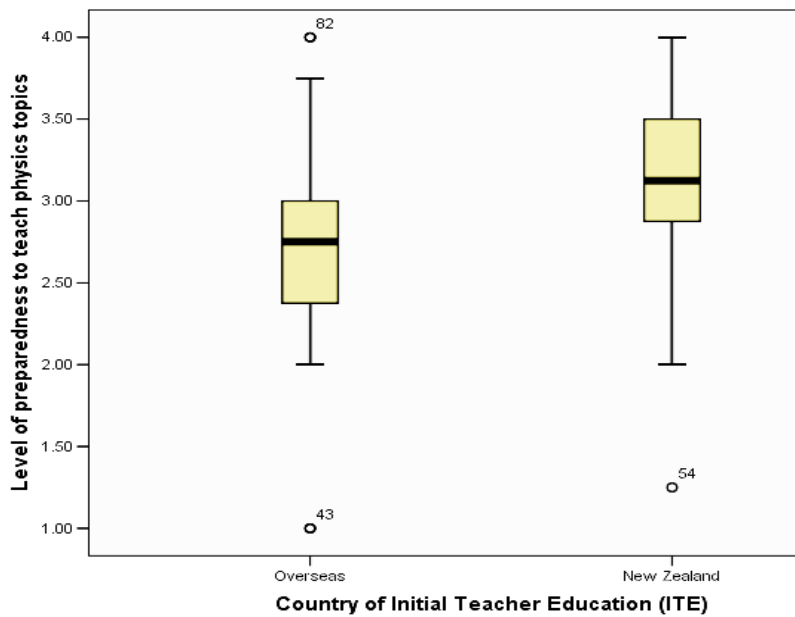


Figure 9: Boxplot showing the distribution pattern of preparedness to teach physics topics

When an independent-samples t-test was conducted to investigate the difference observed in Figure 9, the results of the test, as presented in Table 7, were statistically significant, $t(102) = 2.05$, $p = 0.04$. That is, on the average, teachers trained in New Zealand were more prepared to teach the various physics content areas ($\underline{M} = 3.00$, $\underline{SD} = 0.60$) than those teachers trained overseas ($\underline{M} = 2.72$, $\underline{SD} = 0.65$). In New Zealand the assessment system for physics values recall of content knowledge and teachers trained in New Zealand are perhaps more familiar with the assessment standards than those trained overseas. This might have accounted for the difference observed in perception of the effectiveness of their training.

Table 7: Independent Samples T-Test on Differences in Teachers Preparedness to Teach Various Physics Topics

Variable	Group	N	Mean (M)	Std. dev. (SD)	t	p-value
Teachers preparedness to teach various physics topics	Teachers trained in New Zealand	75	3.00	0.60	2.05	0.04*
	Teachers trained Overseas	29	2.72	0.65		

*Significant, $p < 0.05$ degree of freedom (df) = 102

Effect size statistics (r), also called eta squared, however, showed that the magnitude of the difference observed was small ($r = 0.20$). That is, only 4% of the variance in teacher preparedness to teach various physics topics was explained by the country they received their initial teacher education (ITE) (see Appendix I for the calculation of r). The threshold values for interpreting effect size are given as follows: $r = 0.10$ for small effect; $r = 0.30$ medium or moderate effect; and $r = 0.50$ large effect (Cohen, 1988; Field, 2009; Pallant, 2007).

Understanding Teaching and Learning (UTL) Model

Again, the teachers responded to a number of points on how their ITE prepared them on other interdependent classroom variables. In particular, knowledge of learners and their development, knowledge of subject matter and curriculum goals, and knowledge of teaching which constitute the framework of the UTL model (Darling-Hammond & Baratz-Snowden, 2005). Table 8 shows the teachers' ratings on their preparedness on these constructs (knowledge of learners and their development, knowledge of subject matter, and knowledge of teaching).

Table 8: Teachers' Perception of their Preparedness on the UTL framework (N = 104)

My initial teacher education ...	Percentage responses					Mean	Std. dev.
	SA	A	NS	D	SD		
Knowledge of learner dev. & learning							
Provided background on how children develop and learn	23.1	67.3	4.8	3.8	1.0	4.08	0.72
Equipped me with skills to observe, monitor, and assess children to gain accurate feedback about their learning and development	14.4	60.6	13.5	7.7	3.8	3.74	0.94
Provided background about how children acquire and use language	7.7	41.3	17.3	26.0	7.7	3.13	1.13
Knowledge of subject matter							
Provided knowledge of curriculum goals	20.2	65.4	3.8	9.6	1.0	3.94	0.85
Equipped me with adequate subject matter knowledge	11.5	15.4	9.1	46.7	17.3	2.74	0.89
Enabled me to understand, interpret and implement the national and school curricula	17.0	30.8	11.7	28.7	20.9	2.63	0.93
Incorporated the use of ICT into teaching and learning of physics	9.6	36.5	8.7	28.8	16.3	2.54	1.31
Knowledge of teaching							
Enabled me to teach diverse student population	14.4	55.8	12.5	16.3	1.0	3.66	0.95
Provided background about how to observe an individual student with different tasks and other students to diagnose his/her need	8.7	31.7	22.1	33.7	3.8	3.08	1.08
Focused on the use of inquiry and problem-based learning approaches	5.8	51.9	12.5	26.9	2.9	3.31	1.03
SA=Strongly agree A=Agree NS=Not sure D=Disagree SD=Strongly disagree							

As presented in Table 8, the majority of the teachers were of the view that their ITE experience equipped them with knowledge of learners and their development. More than 90% (SA+A) of the teachers indicated that their ITE provided background knowledge on how learners develop and learn. About 75% also believed that they were equipped with the skills of observation, monitoring and diagnosing learners to gain accurate feedback on their learning and development. Far fewer responded that their ITE provided neither information on skills of observation, monitoring and

assessing to gain feedback on learners and their development. On the other hand, about 64% indicated that their ITE did not equip them with adequate subject matter knowledge. Almost 50% said their training did not enable them to understand, interpret and use both the state and school curricula. There was however, no majority response on the use of ICT in the teaching of physics. This may be a reflection on when they undertook their ITE.

On knowledge of teaching, the mean scores, as seen in Table 8 show that the teachers were not definite in their responses that they were equipped with appropriate knowledge of teaching from their ITE. However, most of the teachers held the view that they were equipped with knowledge about teaching diverse students (3.66). More than one-fourth (29.8%) thought that their training did not focus on the use of inquiry and problem-based approaches, though a slight majority (58.0%) believed that their initial training focused on the use of inquiry and problem-based approaches. Also, a good number of the teachers (about 38%) disagreed that their initial training provided information on assessing students' learning. About representing 22% were also not sure of this claim. Just only about 40% purported that they had knowledge on students' assessment and learning.

One-way analysis between groups multivariate analysis of variance (MANOVA) was performed to investigate any difference among the year groups teachers completed ITE on the three constructs (framework) of UTL. Thus three dependent variables were used: knowledge of learners and their development, knowledge of subject matter and knowledge of teaching. The independent variable was completing year of ITE, which had four levels – 1965-1987, 1988-2000, 2001-2007 and 2008+ respectively. Preliminary assumptions testing were performed to check for univariate and multivariate normality, linearity, equality of variance, homogeneity of covariance matrices, and multicollinearity (Field, 2009; Pallant, 2007; Tabachnick & Fidell, 2007) with no violations noted. The Box's test, for example, was used to test the assumption of homogeneity of covariance matrices. The Box M produced a significant value of 0.030 which is larger than the

threshold value 0.001, hence the assumption of homogeneity of covariance matrices was not violated. If the significant value is less than 0.001 then there is a reason for concern (Field, 2009; Pallant, 2007; Tabachnick & Fidell, 2007). Thus, the observed covariance matrices of the dependent variables were equal among the year groups.

Again, none of the variables recorded significant values under the Levene's Test of Equality of Error Variance. P-values of 0.143, 0.347 and 0.229 were recorded for knowledge of learners and their development, knowledge of subject matter and knowledge of teaching respectively. These values were greater than 0.05, hence the assumption of equality of variance was not violated (Pallant, 2007). A histogram with normal curve was used to inspect the distribution of scores on the dependent variables. Skewness was not extreme (Tabachnick & Fidell, 2007) and produced no cause for concern. Thus, the dependent variables were normally distributed within each year group. A simple correlation was also performed to test the assumption of multicollinearity – “when the dependent variables are highly correlated” (Pallant, 2007, p. 282) which shouldn't be the case when performing MANOVA. If correlations among the dependent variables are up to 0.8 or 0.9 then there is cause for concern. The test showed that the variables were moderately correlated with Pearson correlation values of 0.48, 0.059 and 0.66 (see Appendix J).

The main results of the MANOVA are presented in Table 9. As seen in the table, there are many test statistics to choose from, however, Tabachnick and Fidell (2007) recommend Wilk's Lambda for general use if assumptions are not violated.

Table 9: Multivariate Tests of Significance for Combined UTL

Grouping variable	Effect statistics	Value	F	df	Error df	p-value	Partial eta squared
Completing year of ITE	Pillai's Trace	0.206	2.459	9.00	300.00	0.010	0.069
	Wilk's Lambda	0.802	2.517	9.00	238.66	0.009*	0.071
	Hotelling's Trace	0.237	2.545	9.00	290.00	0.008	0.073
	Roy's Largest Root	.0183	6.088	3.00	100.00	0.001	0.154

*Significant, $p < 0.05$

As seen in Table 9, a Wilk's Lambda of 0.802 with a significance value of 0.009 was recorded. The significance value is less than 0.05, therefore using Wilk's Lambda statistics, there was a statistically significant difference among the year groups on the combined three constructs of UTL: $F(9, 238.7) = 2.52$, $p = 0.01$; partial eta squared = 0.071. When the results of the test (dependent variables) were considered separately, Table 10 shows that the only difference to reach a statistical significance was knowledge of subject matter with a p-value of 0.001 and an eta squared value of 0.149. This means that the only significant difference among the year groups was on their subject matter content knowledge.

Table 10: Tests of Between-Subject Effects for UTL Sub-scales

Grouping variable	Dependent variables	Type III sum of squares	F	df	Mean squares	p-value	Partial eta squared
Completing year of ITE	Knowledge of learners and their development.	3.781	2.527	3	1.260	0.062	0.070
	Knowledge of subject matter	7.814	5.814	3	2.605	0.001*	0.149
	Knowledge of teaching	3.245	2.028	3	1.082	0.115	0.057

*Significant, $p < 0.05$

In view of the significant difference established, the three constructs (dependent variables) were considered for post hoc analysis using Bonferroni correction of 0.017 (Field, 2009; Pallant, 2007; Tabachnick & Fidell, 2007) with the Games-Howell procedure as an alternative comparison due to the conservative nature of the Bonferroni correction (Field, 2009). The results of the post hoc test, as seen in Appendix K, supported the findings in Table 10, i.e. the only variable to reach a statistical significance using the Bonferroni correction and Games-Howell procedure was knowledge of subject matter. An inspection of the table in Appendix K shows that the difference on knowledge of subject matter actually existed between teachers who completed ITE in the year 1965-1987 and those who completed in 2001-2007 (p-value = 0.05) and 2008+ (p-value = 0.001). There was no significance difference between those who completed in 1965-1987 and 1988-2000. An examination of the estimated marginal mean scores shown in Table 11 indicated that teachers who completed in 2001-2007 (\underline{M} = 3.69, \underline{SD} = 0.54) and 2008+ (\underline{M} = 3.94, \underline{SD} = 0.61) reported higher level of knowledge of subject matter than their counterparts who completed in 1965-1987 (\underline{M} = 3.19, \underline{SD} = 0.81).

Table 11: Estimated Marginal Mean Scores for the ITE Completion Year Groups

	Year group	Mean	Std. dev.
Knowledge of subject matter	1965-1987	3.185	0.808
	1988-2000	3.630	0.675
	2001-2007	3.694	0.538
	2008+	3.936	0.611

Physics Classroom Interactions – Teaching Strategies and Practices

Research question three was intended to find out what happens in the physics classrooms in New Zealand and what students studying physics would like to happen. The questionnaire asked both physics teachers and students to indicate on a five-point Likert scale (with extreme alternatives of Never – Always) how often particular teaching strategies and practices happen in their physics classrooms. Students were also asked to indicate how often they would like these strategies and practices to be applied. The practices were grouped under the following sub-headings: teaching approaches, teacher feedback and guidance, and ICT usage in physics teaching. The following sections look at the responses of the physics teachers. The students' responses are presented in a separate section – “Analysis of Students' Survey Questionnaire.”

Physics Classroom Interactions – Teachers' Perspective

This section reports the findings of the physics teacher's responses to the rating-scale items on teaching approaches, teacher feedback and guidance and ICT usage in physics teaching. The teachers' responses were coded and ranked in a five-point Likert scale format with 'Never'=1; 'Not Often'=2; 'Sometimes'=3; 'Most of the Time'=4; and 'Always'=5 respectively. The mean scores and standard deviation (SD) of items on the sub-scales (teaching approaches, teacher feedback and guidance and ICT usage) by school decile ranking are presented in Table 12, Table 13 and Table 14 respectively. The percentage responses are presented in Appendix L.

As can be seen in Table 12, the teachers responded to many points about what actually takes place in the physics classroom regarding their teaching methods. The overall mean scores and standard deviations on this sub-scale were: decile 1-3 ($\underline{M} = 3.31$, $\underline{SD} = 0.75$); decile 4-7 ($\underline{M} = 3.41$, $\underline{SD} = 0.75$); and decile 8-10 ($\underline{M} = 3.37$, $\underline{SD} = 0.75$) respectively. These give an indication that physics teachers sometimes use the said teaching strategies indicated in Table 12. It can be seen that presentation of new concepts and problem solving are most often done on the white board. Teachers from decile 1-3 and 4-7 schools most of the time emphasized mathematical presentation

of concepts more than their colleagues in decile 8-10 schools. Teachers from decile 4-7 and 8-10 schools on the other hand, recorded high mean scores (3.82 and 3.90) on qualitative thinking and presentation of concepts – an essential feature of teaching by inquiry.

Table 12: Means and Standard Deviation Scores of Items on Teaching Approaches by Schools' Decile Ranking

Statements	Decile ranking					
	1-3 (N=9)		4-7 (N=44)		8-10 (N=51)	
	Mean	SD	Mean	SD	Mean	SD
I present new materials on white board	3.22	0.67	3.55	0.98	3.61	0.83
I demonstrate problem-solving on the white board	3.89	0.78	3.91	0.77	3.88	0.74
I place emphasis on mathematical presentation of concepts	3.56	1.13	3.73	0.92	3.35	0.93
I place emphasis on qualitative thinking and presentation of concepts	3.33	0.87	3.82	0.79	3.90	0.81
I use demonstrations and discussions to illustrate concepts/phenomena	3.44	0.73	3.73	0.59	4.04	0.80
Teaching and learning is teacher-centred	3.44	0.53	3.50	0.63	3.51	0.61
Teaching and learning is student-centred	2.89	0.78	2.80	0.55	2.76	0.68
I use students' suggestions and ideas in teaching	3.33	0.71	3.34	0.81	3.22	0.76
I engage students in context based-activities	3.56	0.88	3.23	0.71	3.27	0.80
Students work with physics problems individually	3.11	0.78	3.23	0.74	3.33	0.59
Students work with physics problems in groups	3.56	0.53	3.30	0.67	3.16	0.58
Students have opportunity to explain their own ideas	3.56	0.88	3.70	0.70	3.51	0.81
Students do experiments by following instructions from the teacher	3.00	0.71	3.23	0.81	3.39	0.70
Students plan and do their own experiments	2.44	0.53	2.64	0.89	2.49	0.86
Average scores	3.31	0.75	3.41	0.75	3.39	0.75

Teachers from decile 4-7 and 8-10 schools also reported high mean scores (3.73 and 4.04 respectively) for the use of demonstrations and discussions to illustrate concepts/phenomena. It can also be seen that almost all of the teachers indicated that teaching and learning is rarely student-centred. In addition, students' ideas and suggestions were not often used in teaching. Also, students were not likely to have opportunities to plan and carry out their own designs for experiments, as most often they would perform experiments by following teacher instructions.

Teacher feedback and guidance was the next sub-scale under classroom interaction. Items on this sub-scale were used to find out how physics teachers related, encouraged, motivated and showed interest in their students' learning. The mean scores and standard deviations of the items by decile ranking are shown in Table 13.

Table 13: Means and Standard Deviation Scores of Items on Teacher Feedback and Guidance

Statements	Decile ranking					
	1-3 (N=9)		4-7 (N=44)		8-10 (N=51)	
	Mean	SD	Mean	SD	Mean	SD
Tell students how they can improve their performance	4.22	0.83	3.93	0.66	3.90	0.67
Give quizzes that I mark to see how students are performing	2.33	1.12	2.89	0.84	3.00	0.66
Talk to students about how they are getting on in physics	3.78	0.83	3.82	0.82	3.55	0.78
Mark students' work and give it back quickly	3.78	0.97	4.07	0.76	3.92	0.82
Use language that is easy to understand	4.44	0.53	4.20	0.59	4.24	0.68
Show students how new concepts in physics relate to what we have already done	4.11	0.93	4.09	0.74	4.14	0.77
Average scores	3.78	0.87	3.83	0.74	3.79	0.73

As provided in Table 13, the overall mean scores and standard deviations for the teachers on teacher feedback and guidance were as follows: decile 1-3 ($\underline{M} = 3.78$, $\underline{SD} = 0.87$); decile 4-7 ($\underline{M} = 3.83$, $\underline{SD} = 0.74$); and decile 8-10 ($\underline{M} = 3.79$, $\underline{SD} = 0.73$). This indicates that teachers in the survey perceived their response and assistance to students to be important. That is, most of the time, teachers in the survey showed interest in their students' learning and provided the needed motivation and encouragement to students. The item "I use language that is easy to understand" for example, was rated to be the most positive with mean value of 4.44 and standard deviation of 0.53 for teachers of decile 1-3 schools, mean value of 4.20 and standard deviation of 0.59 for teachers of decile 4-7 schools and mean value of 4.24 and standard deviation of 0.68 for teachers of decile 8-10 schools.

From the frequency table, as shown in Appendix L (section 2), 36 (34.6%) of the teachers responded "Always" and 57 (54.8%) responded "most of the time" to this item. Only 11 (10.6%) teachers selected "sometimes" to the item. "Not often" and "never" recorded no responses as seen in Appendix L. Likewise, items "I tell students how they can improve their performance" and "I show students how new concepts in physics relate to what we have already done" were also rated positive by the teachers as seen from the mean scores in Table 13. Also seen in Appendix L, the majority of the teachers responded positively to these items against only 2 (1.9%) teachers who felt they "not often" show students how new concepts in physics relate to what they have already done.

On the other hand, formative types of assessment in classrooms, such as giving quizzes and marking them to see how students are performing rarely happened, as almost all the teachers reported negatively (low ranking) on this item. A low mean score of 2.33 and standard deviation of 1.12 were recorded for teachers of decile 1-3 schools; 2.89 and 0.89 mean and standard deviation values for decile 4-7; and 3.00 and 0.66 mean and standard deviation values for decile 8-10 school teachers. The mean values were far below the average mean score as indicated in

Table 13. This is confirmed by the frequency and percentage table in Appendix L (section 2) as only about 53% of the teachers ‘sometimes’ give quizzes to evaluate their students’ performance.

The third sub-scale, ICT usage in physics teaching, was used to find out how often physics teachers use ICT tools to enhance teaching and learning of physics. As shown in Table 14, the overall mean scores and standard deviations for the teachers by their schools’ decile ranking were as follows: \underline{M} = 2.47 and \underline{SD} = 0.83, \underline{M} = 2.60 and \underline{SD} = 0.90, and \underline{M} = 2.80 and \underline{SD} = 0.81 for decile 1-3, 4-7, and 8-10 schools respectively. The mean scores for all five questions related to the use of ICT indicated that the majority of physics teachers used ICT tools sporadically or rarely at all.

Table 14: Means and Standard Deviation Scores of Items on ICT Usage in Physics Teaching

Statements	Decile ranking					
	1-3 (N=9)		4-7 (N=44)		8-10 (N=51)	
	Mean	SD	Mean	SD	Mean	SD
Use computers for laboratory simulations	2.44	1.01	2.70	0.95	3.00	0.78
We look for information on the internet at school	2.89	0.78	2.95	0.96	2.80	0.72
Use computers to collect and/or analyze data	2.22	0.67	2.39	0.90	2.65	0.96
Use computers to demonstrate physics principles	2.89	0.78	2.84	0.71	3.00	0.63
Students use their phones to search for information at school	1.89	0.93	2.11	0.97	2.55	0.95
Average scores	2.47	0.83	2.60	0.90	2.80	0.81

From the frequency and percentages tables shown in Appendix L (section 3), less than a quarter, 19 (18.3%), of the teachers reported that they “always” and “most of the time” used computers for laboratory simulations. The majority of the teachers 77 (74.1%) sporadically used computers for laboratory simulation. Similar results were seen for the use of ICT tools to: search for information on the internet at school; collect and/or analyze data; and demonstrate physics principles, as in all

cases, the majority of the teachers only occasionally used ICT tools for such purposes. As can also be seen, the majority of the teachers (67.3%) reported that students rarely use their phones to search for information at school. About 27% of the teachers mentioned that students never used their phones to search for information at school.

Differences in Classroom Interactions between the Decile Ranking Schools

To find out whether the means scores observed in Table 12, Table 13 and Table 14 were statistically significant between the decile ranking schools, a one-way analysis between groups multivariate analysis of variance (MANOVA) was conducted after initial testing of assumptions was performed. Preliminary evaluation of assumptions of univariate and multivariate normality, linearity, homogeneity of variance-covariance matrices, equality of variance and multicollinearity were satisfactory, with no serious violations identified (see Appendix M). However, one variable, usage of ICT in physics teaching, recorded a significance value of 0.03 under the Levene's Test of Equality of Error Variance. Since this value (0.03) is less than 0.05 the said variable (usage of ICT in physics teaching) did not meet the assumption of equality of variance. In such situations, Tabachnick and Fidell (2007) recommend that Pillai's trace criterion should be reported for the combined test of significance because it is "more robust for small sample sizes, uneven N values and violation of assumptions" (Pallant, 2007, p. 286)

With the use of Pillai's trace criterion, as shown in Table 15, the results of the combined dependent variables (teaching approaches, teacher feedback and guidance and ICT usage in physics teaching) were not statistically significant for the decile ranking schools, $F(6, 200) = 0.98$, $p = 0.44$; partial eta squared = 0.03.

Table 15: Multivariate Test of Significance for Combined Classroom Interactions

Grouping variable	Effect statistics	Value	F	df	Error df	p-value	Partial eta squared
Decile ranking of schools	Pillai's Trace	0.057	0.976	6.00	200.00	0.442*	0.028
	Wilk's Lambda	0.943	0.975	6.00	198.00	0.444	0.029
	Hotelling's Trace	0.060	0.973	6.00	196.00	0.445	0.029
	Roy's Largest Root	0.052	1.747	3.00	100.00	0.162	0.050

*Not significant, $p > 0.05$

This means that physics teachers across the schools do not differ in terms of their classroom interactions. They have similar teaching approaches and also related to students in a similar manner. The estimated marginal means indicated in Table 16 further show that the means scores on each construct were almost the same for all schools.

Table 16: Estimated Marginal Mean Scores for the Classroom Interactions

Construct	Decile ranking	Mean	Std. dev.
Teaching approaches	1-3	3.31	0.34
	4-7	3.41	0.32
	8-10	3.39	0.29
Teacher feedback and guidance	1-3	3.78	0.67
	4-7	3.83	0.45
	8-10	3.79	0.43
ICT usage in teaching physics	1-3	2.47	0.57
	4-7	2.60	0.65
	8-10	2.80	0.44

Areas of Professional Learning

As noted by Weiss et al. (2001), making curriculum and instructional decisions is one of the hallmarks of teachers as professionals. Added to this is keeping up with advances in their field. Research question four therefore sought to look at pertinent areas of professional learning that physics teachers would like to have as far as their teaching practice was concerned. In the questionnaire, physics teachers were asked to indicate how important they think professional learning is in a number of areas about professional development. The areas of professional learning included: use of technology in physics instruction; use of inquiry/investigation-oriented teaching strategies; understanding student thinking in physics; how to assess student learning in physics; deepening teacher's own content knowledge; and knowledge of the New Zealand curriculum.

On a five-point Likert scale from 1 (not important) to 5 (very important), the teachers reported a substantial need for professional development in each of the areas. As can be seen in Figure 10, the majority of the teachers reported that they needed professional development related to understanding student thinking in physics (95.2%) and deepening teacher's own content knowledge (93.3%). Professional development having to do with assessing students and the use of inquiry/investigation-oriented teaching strategies were also rated highly by the teachers. About three-quarters of the teachers also reported a need for professional learning regarding the use of technology in physics instruction and knowledge of the New Zealand curriculum. In each case, only a few minorities were less likely to perceive that they needed professional development in these areas.

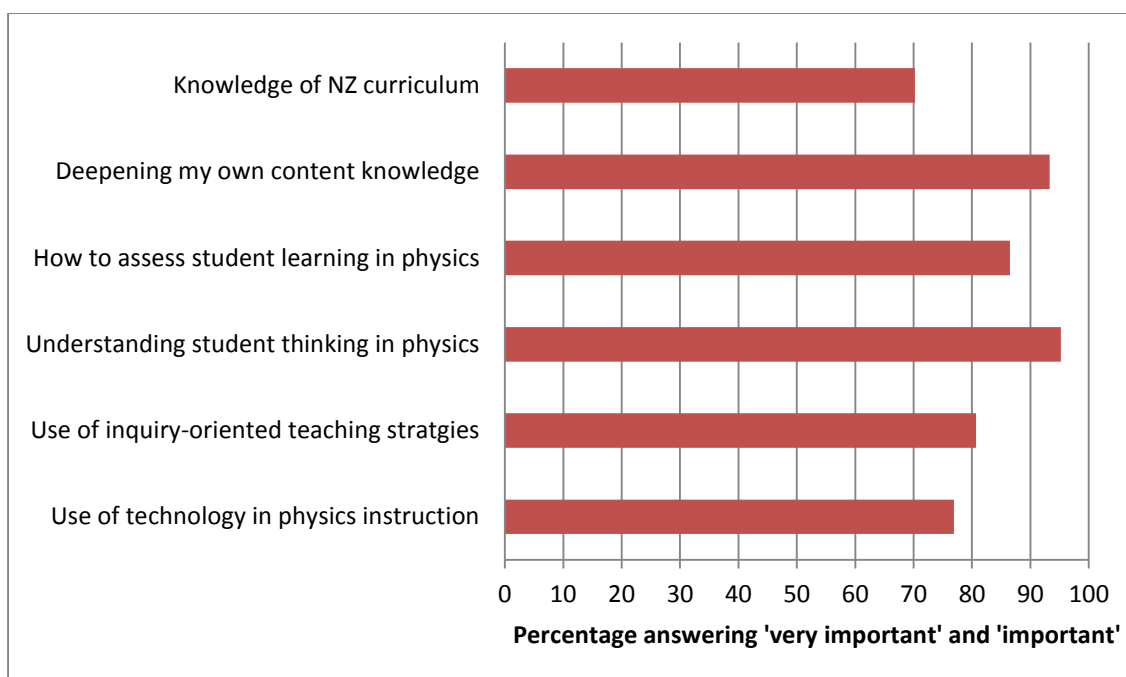


Figure 10: Percentage of teachers rating “very important” and “important” for areas of professional learning

Similar observations were recorded in the perceived areas of professional development for teachers whose first choice teaching subject was physics and those who changed to physics. Figure 11 shows the distribution of percentage scores for both groups answering ‘very important’ and ‘important’. Almost all the teachers in these groups perceived that they needed a moderate or substantial professional development in all the areas. Both groups of teachers reported a significant need for professional learning in the areas related to deepening teacher’s content knowledge and understanding student thinking in the subject.

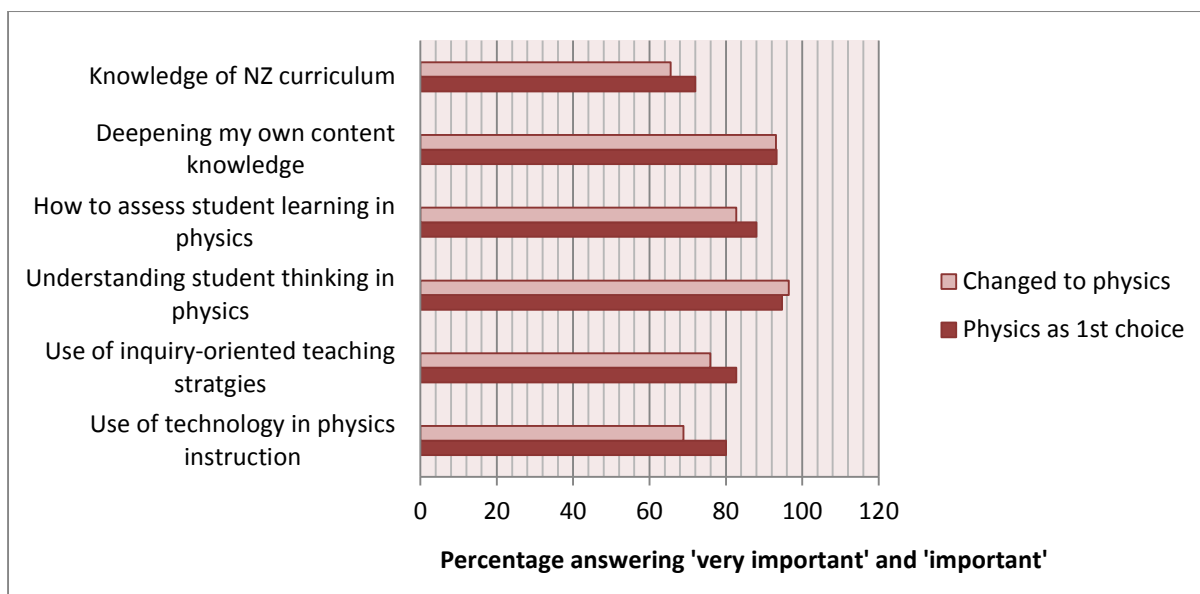


Figure 11: Comparison of teachers rating “very important” and “important” to areas of professional learning

When asked to indicate the types of professional development activities teachers have undertaken during the preceding five years, Table 17 shows that meeting with a local group of physics teachers on a regular basis to study/discuss issues about physics teaching was the most commonly reported form of professional development. About 79% of teachers whose first choice teaching subject was physics and 69.0% of those who switched to physics reported this activity. The second most common professional learning activity reported by both groups of teachers was deepening their subject matter content knowledge followed by learning how to use inquiry/investigation-oriented teaching strategies.

On the other hand, learning how to use technology in physics instruction appeared not to be common and regular form of professional development for the teachers. Also, ‘collaboration on physics teaching with a group of physics teachers at a distance’ and ‘served as a mentor and/or peer coach in physics teaching, as part of a formal arrangement that is recognized or supported by the school’ seemed not to be common and regular forms for professional development for most of the teachers (both teachers with physics as first choice teaching subject and those who switched to physics) who participated in the study.

Table 17: Types of Professional Development Activities Teachers have undertaken

Professional development activities	Percentage responses			
	Physics as 1 st choice teaching subject (N=75)		Teachers who switched to physics (N=29)	
	Yes	No	Yes	No
Learning how to use technology in physics instruction	43.2	56.8	34.5	65.5
Learning how to use inquiry/investigation-oriented teaching strategies	74.7	25.3	72.4	27.6
Understanding student thinking in physics	48.0	52.0	24.1	75.9
Learning how to assess student learning in physics	64.0	36.0	58.6	41.4
Deepening my own physics content knowledge	77.3	22.7	79.3	20.7
Observed other teachers teaching physics as part of teacher's professional development (formal or informal)	53.3	46.7	58.6	41.4
Met with a local group of physics teachers on a regular basis to study/discuss issues about physics teaching	78.7	21.3	69.0	31.0
Collaborated on physics teaching with a group of physics teachers at a distance	49.3	50.7	44.8	55.2
Served as a mentor and/or peer coach in physics teaching, as part of a formal arrangement that is recognized or supported by the school	42.7	57.3	10.3	89.7

Factors Constraining the Quality Teaching and Learning of Physics

Factors constraining the quality teaching and learning of high school physics was the focus of research question five. In the questionnaire, the teachers indicated the extent to which they perceived particular factors hindered the quality teaching and learning of high school physics. In addition, an open ended item was used to elicit other factors that the teachers felt were key to the issue under discussion. The teachers' responses to the closed items were coded and ranked using a scale of 1(strongly disagree) to 5(strongly agree), where 5 is the highest. Table 18 shows the percentage responses, mean scores and standard deviation for each item.

From the percentage distribution of responses and the mean scores in Table 18 the teachers perceived that the most important factors limiting the quality teaching and learning of physics were assessment and NCEA requirements (with a mean score of 4.01); parental and societal perception about the difficulty of physics (3.86); students' misconception about physics (3.85); and the interface between mathematics and physics (3.81). Lack of technical support, inadequate physics teachers and inadequate education of physics of teachers were the next popular factors perceived by the teachers. Mean scores of 3.65, 3.63 and 3.61 were recorded for lack of technical support, inadequate physics teachers and inadequate education of physics teachers respectively.

Table 18: Percentage and Mean Scores for Perceived Limiting Factors of Quality Physics Teaching and Learning

Perceived factors	Percentage responses (N=104)					Mean	Std. dev.
	SA	A	NS	D	SD		
Students' misconceptions about physics	16.3	65.4	4.8	13.5	-	3.85	0.86
Parental and societal perception about the difficulty of physics	18.3	61.5	8.7	10.6	1.0	3.86	0.88
Inadequate education of physics teachers	16.3	54.8	6.7	17.3	4.8	3.61	1.10
The connection between mathematics and physics	20.2	58.7	5.8	12.5	2.9	3.81	1.00
Lack of teacher motivation	5.8	26.9	8.7	39.4	19.2	2.61	1.23
Inadequate teacher subject knowledge	11.5	52.9	10.6	16.3	8.7	3.42	1.16
An overloaded curriculum	13.5	36.5	19.2	26.0	4.8	3.28	1.14
Insufficient classroom teaching time	14.4	44.2	15.4	25.0	1.0	3.46	1.05
Inadequate physics teachers	25.0	43.3	6.7	19.2	5.8	3.63	1.22
Inadequate laboratory equipment	9.6	39.4	15.4	34.6	1.0	3.22	1.06
Lack of technical support	14.4	57.7	8.7	17.3	1.9	3.65	0.99
Assessment and NCEA requirements	25.0	58.7	8.7	7.7	-	4.01	0.81
Lack of teacher mentors	5.8	37.5	34.6	21.2	1.0	3.26	0.89
SA=Strongly agree A=Agree NS=Not sure D=Disagree SD=Strongly disagree							

The open-ended item which sought to elicit, from the teachers their opinion about what were other key factors, resulted in about 87 individual responses. Some of the teachers used the open-ended item as an opportunity to iterate and expand on some of the factors responded to in Table 18. The responses given by the teachers fell into one of the following categories: assessment; curriculum and timetabling; junior science; teacher factor and pedagogy; perceived nature of physics; and weak mathematics background.

Assessment

The physics teachers indicated that one of the biggest limitations to the quality teaching and learning of senior physics in New Zealand is NCEA and its related requirements. The teachers thought that physics teaching is driven by assessment, not by students' interests, and that this is because of schools' emphasis on performance and grades. In the teachers view, many students don't want to know "how to do physics" or "think in a physics way", they just want the qualification so they can move on. This was described by the teachers as prevalent and damaging. Also, the teachers mentioned that university entry requirements, together with school requirements for students to gain credits, are making the teaching of physics extremely demanding and difficult for both teachers and learners. Entry requirements imposed by universities for particular courses (for example specific achievement standard completion for entry to engineering), was mentioned as one of those things that really limits the flexibility that could be available. Again, the teachers believed too many credits are offered externally and that the external assessments have precluded capable physics students from carrying on further studies with physics. One physics teacher bemoaned:

The external assessment tasks have proven difficult for students to identify what the question is asking for. There has certainly been a clear shifting of 'expected standard of answers' from year to year. I have observed a very

talented physics student bomb out in the final exam, not due to lack of Physics knowledge, but simply not providing the answer that the examiner is looking for. The student used a kinematic equation and logical deduction to answer a question BUT the examiner was requiring the use of conservation of energy ideas – even though the question did not distinguish this. (High School physics teacher).

Curriculum and Timetabling

On curriculum and timetabling, the teachers observed that the curriculum document (both National and School Curricula) are limiting and they do not clearly specify or describe what is required to be taught for the physics achievement standards. In many cases, the teachers indicated that the curriculum is just “heavy with words” and has compounded the problem. One physics teacher had this to say:

Give the teaching staff a syllabus, not just vague statements which don't really describe what is needed for the standard. The free and easy flexibility of we can teach what “we like” does NOT APPLY to external examinations. I need to know what knowledge and the depth of knowledge needed for the examination.
(High School physics teacher)

Another stated:

... we're teaching Physics which is essentially pre 1908, so at times it's almost a historical science type course and because of that, if we're not very careful it can be a little bit dry, it can... and by dry I think I mean boring. (High School physics teacher)

Time constraint was one major reason mentioned by most of the participants. The teachers were of the view that the school timetable and a very full curriculum did not provide enough time for lesson preparation or time for students to experiment with concepts and practise and organizing remedial lessons for individual students. One teacher stated:

We are always under pressure to get everything done so there is not such a time to personalise learning experiences for individual students. I have experienced this for many years...and have heard many other New Zealand physics teachers complaining about this. (High School physics teacher)

Junior Science

Some of the teachers bemoaned that the Junior Science does not provide adequate preparation for students to pursue Levels 2 and 3 physics. They observed that because of the integrated way science is taught at junior level, some students may not meet a physics teacher until Year 12 when they have already formed their misconceptions and made choices for subjects in the senior years. They further indicated that many students do not start to do real science until Year 9 and even then the physics teaching at junior level is poor because the biology teachers who teach junior science shy away from it and have little passion for it or may have persistent misconceptions themselves. One teacher remarked:

Progression in physics through lower levels taught by non-physicists is a major problem. Often students come to senior physics with misconceptions from learning physics in junior school by teachers not having adequate physics knowledge. Besides completing the curriculum within a set time, senior physics teachers have to constantly spend time erasing those misconceptions, which could be overcome with robust physics teaching in Years 9 and 10. (High School physics teacher)

Another teacher also remarked:

Science division into physics, chemistry and biology at Level 1 has most often led students away from physics since they don't have the required prerequisites to take up physics again in Level 2 or 3...lack of good primary/intermediate preparation....other Science teachers don't understand Physics, they are scared by it and try to put physics on the back-burner at Junior Science levels. (High School physics teacher)

Teacher Factor and Pedagogy

Some of the teachers were clear that recruitment and retention of qualified physics teachers (especially but not always in the low decile schools), low numbers of teachers with a physics degree and their own limited competencies and subject matter knowledge are contributing factors to the quality teaching and learning of physics. They also indicated many schools have only one physics teacher and therefore a lack of collegial support makes it difficult for such teachers to improve or develop their teaching practice and content knowledge. This also means that the physics teacher is usually kept busy with teaching senior classes and therefore does not come in contact with many students in junior science classes.

On pedagogy, the physics teachers who responded to this question admitted that physics was not often taught in a way that allowed it to be applied to everyday life, hence students could not really see the subject as a "life science". According to them, the majority of physics teaching is often the very traditional "talk and chalk" compared to other learning areas where students are much more involved in activities and group work. The teachers appeared to be objective about the issues as they mentioned that a lot of physics teachers did not themselves experience teaching other than by traditional methods and they were just practicing what they know. This approach to

teaching, to them, had caused many students to withdraw from physics studies. One physics teacher offered this comment:

A lot of physics teachers don't know how to get students to discuss things in groups and slow down and teach them how to access the physics in terms of literacy understanding and how to unpack just the language around physics and therefore resort to the old method of teaching...well they think it worked for me, why shouldn't it work for these students. Most of them are teaching as they were taught. (Physics teacher)

Perceived Nature of Physics

The public and students' perception of physics as an abstract and difficult subject was seen as one of the major hindrances to quality teaching and learning of the subject. The teachers believed that this negative perception has done more harm than good to the physics fraternity (especially in the area of education) to the extent that a greater number of potential students had been lost during their early years at school. The comments by the teachers suggested that most of their students had an impression that the subject is difficult and therefore they choose to spend not much time studying it. The teachers thought that most of these students aimed to get only satisfactory performance (Achieved level) in the assessments. Only a few strive for good performance (Merit) or outstanding performance (Excellent).

Again, the teachers observed that there is an overload of content demand for external examinations, which lead to many teachers resorting to teaching students how to pass exams rather than really understanding the concepts deeply and applying them to real life situations. This, according to the teachers has in one way or another supported the public and students' poor view of physics, which has contributed to the low interest level by students. One teacher remarked:

Media perception of physics as hard, the fact that it is easier to get excellence in other subjects, mean physics is hard and too technical, not everyone can do it. (Physics teacher)

Weak Mathematics Background

The teachers admitted that physics involves mathematics (calculations and equations) and that physics becomes very mathematical at the higher levels, which means a weak background in mathematics makes the subject very difficult to learn. Thus, one needs to have a strong background in mathematics to succeed in physics studies. They indicated that students' poor mathematical ability is one of the reasons why many students opt out of physics studies and/or are not doing well in the subject. Some of the teachers held the view that student lack of perseverance when trying to grasp a concept or calculation caused them, to give up. Others thought that student conceptual and mathematical understanding from Junior Science is often patchy and that this has slowed the progress of teaching and learning of senior physics. One teacher offered:

The other big issue I see is the lack of ability to rearrange basic equations. I am constantly amazed by what a stumbling block this is to so many students in the senior school. (Physics teacher)

One other factor that was mentioned by a few of the teachers was gender stereotyping. They believed that there is societal pressure that prevents females from studying physics. That is, many girls do not take the subject because it is perceived as a boys' subject. They advised that if these pressures are removed, there will be more female students and so more students in total. One indicated:

Many girls do not take physics because it is seen as a masculine subject. However, I have found that the smaller number of girls who do take Physics tend to do better than the boys. I wonder which female students are opting out

because they see it as a subject for boys - and thus truncating their list of options. (Physics teacher)

Improving Teaching and Learning of Physics and Numbers Involved

The last question, research question six, was aimed at exploring ways to improve the teaching and learning of high school physics and the number of students wanting to be trained as physics teachers. Data to answer this question were obtained from physics teachers, high school physics students, initial teacher educators and other stakeholders. The findings from the physics teachers who participated in the survey are presented below.

In the questionnaire, the teachers indicated the extent to which some perceived changes that needed to occur would help improve teaching and learning of high school physics. Their responses were coded and ranked on a five-point Likert scale from 1 (strongly disagree) to 5 (strongly agree). In addition, an open-ended question asked the teachers to suggest ways for improving the teaching and learning of physics and the numbers of students wanting to be trained as physics teachers. Table 19 provides a summary of percentage and mean scores of the teachers' responses to the perceived changes.

Table 19: Percentage and Mean Scores of Perceived Changes for Improving Teaching and Learning of Physics

Perceived factors	Percentage responses (N=104)					Std.	
	SA	A	NS	D	SD	Mean	dev.
Better pre-service education	10.6	47.1	28.8	12.5	1.0	3.54	0.88
Physics cluster meetings to collaborate ideas on physics teaching	22.1	59.6	15.4	1.9	1.0	4.00	0.74
More teacher professional development on physics practicals	19.2	57.7	16.3	5.8	1.0	3.88	0.82
More physics graduates encouraged and/or supported to be trained as teachers	32.7	44.2	16.3	4.8	1.9	4.01	0.93
Reduction in assessment changes from NZQA and MOE	23.1	35.6	24.0	16.3	1.0	3.63	1.04
Better salary and/or incentives for physics teachers	39.4	32.7	15.4	9.6	2.9	3.96	1.10

As seen in Table 19, all the perceived changes were rated positive (high) by the teachers as all items recorded a mean score of 3.5 or above. About 80% of the teachers believed that to improve the quality of physics teaching and learning and to increase the numbers involved, more physics graduates should be encouraged and supported to be trained as teachers. This item had a mean score of 4.01 and standard deviation of 0.93. In addition the teachers would like to see more physics cluster meetings where they collaborated and shared ideas on physics teaching, about 82% perceived this would be a positive (mean score of 4.00) change. Also, about 72% indicated that better salary and remuneration for physics teachers would help improve both the teaching and numbers of students who want to study physics beyond high school level and physics graduates wanting to become teachers.

The open-ended question, which asked teachers to suggest ways for improving the teaching and learning of senior physics and the number of students involved, yielded 98 individual

responses. The suggestions for improvement provided by the teachers fell into the following categories:

1. improved salary and support
2. reducing curriculum content and assessment requirements
3. improved physics and mathematics tuition at junior level
4. more professional development on content knowledge and
5. more qualified physics teachers

Table 20 shows the distribution of responses and Table 21 presents examples of responses in each category.

Table 20: Physics Teachers Suggestions for Improving Teaching and Learning of Senior Physics (N = 98)

Category	N	%
Improved salary and support	21	21.4
Reduction in curriculum content and assessment requirements	30	30.6
Improved physics and mathematics tuition at junior level	15	15.3
Professional development on content knowledge	15	15.3
More qualified physics teachers	17	17.3

The most common suggestions for improving physics teaching and learning and the numbers of students participating as indicated by teachers included reducing curriculum content and assessment requirement (30.6%); better salary and support for physics teachers (21.4%); having more qualified physics teachers (17.3%) and professional learning on subject matter content knowledge (15.3%); and good physics and mathematics teaching at junior level (15.3%).

Table 21: Category and Examples of Suggestion for Improvement

Category	Examples
Better salary and support	<ul style="list-style-type: none"> - There needs to be better pay and better conditions all round to entice new graduates into the profession. The low esteem and the accompanying lower salaries (than graduates of physics and engineering can get elsewhere) mean that only those who have no other options OR those with a burning hunger to be teachers enter the profession. - Encourage and support more students into physics teaching. We don't do enough to encourage potential teachers and we do close a lot of people who have potentials. - Better resource materials to support physics teachers - especially those who are not from a strong physics background. We need a definitive text book which covers the <i>NZC</i>
Curriculum and assessment requirements	<ul style="list-style-type: none"> - We race through the curriculum to be ready for exams, there is no time to teach physics, no time to experiment with concepts and practise, teaching contents esp. 3.6 is pretty dry and that is putting many students off. - Assessment is getting more and more ridiculous of what these students have to answer. They don't do any actual experimental design. The ability to address topics and concepts outside <i>NZC</i> is vital so I believe that teaching physics rather than 'what is in the test' would make a vast difference. We don't do anything on heat, metal expansion or anything close to it, yet, this is what the engineers want. - Reduction of emphasis of assessment. Students are pushed harder and harder to pass. Removal of pedantic assessments such as 2.1 and 3.1 would help
Good physics and mathematics teaching at junior level	<ul style="list-style-type: none"> - Most students are introduced to physics by teachers who are not specialists in years 9-11. This often leads to poor teaching of concepts - more of a focus on how to do things, but not understanding the why and the bigger picture. If we truly want to improve teaching and learning of high school physics then more input from physics specialists into the planning and better

	<p>approaches to teach junior science courses in order to a) enthuse students when they are younger and b) to help reduce the common misconceptions that can hinder understanding in later years.</p> <ul style="list-style-type: none"> - General Science teachers need a better understanding of physics concepts so that aspects of both Mechanics and Electricity can be covered more adequately in junior science so that students have a stronger background when they come into senior physics. - To improve learning there needs to be better teaching of mathematics at primary and the early years at high school. To teach pupils to be confident with arithmetic, trigonometry and algebra rather than all the so-called 'understanding' of mathematics taught today, this does not help building pupils' confidence. If their Mathematics was good then more time could be spent considering the concepts of physics and its applications. - A stronger emphasis upon mastery of mathematical concepts would eventually lead to more student satisfaction at their own progress and a greater sense of achievement. Greater success leads to greater student satisfaction.
Professional development on content knowledge	<ul style="list-style-type: none"> - More professional development required on ideas about better approaches to teaching of content, resources and practicals - Some in-service training to better suit teachers like me who are teaching L3 physics because there is nobody else (in my school) who can do it. - Better training of how to teach Physics, with sample lesson plans for all topics and practicals provided. - Cluster meetings are essential for staff working on their own in 'small schools', few teachers take the time or have the money / budget to attend conferences. Best practice workshops run by the NZQA & MoE moderator are worth their weight in gold - but these are limited to a small number of physics teachers and only happen once per year.
More qualified physics teachers	<ul style="list-style-type: none"> - Biggest issue is the number of qualified physics teachers that are available. We need more physics trained teachers. - If there were more qualified physics teachers available you would see a marked improvement in the quality of student results. Unfortunately, new

physics graduates often look to industry, rather than the teaching sector for their career, as it is more lucrative.

- Encourage more physics graduates into teaching. Specialist physicists will be in a better position to do a good job at L2 & L3 and students will be more attracted to studying the subject.
 - Have more physics graduates enter the profession, not a chemist like me who...encourage more young, enthusiastic and motivated physics graduates into the profession
-

Analysis of Students' Survey Questionnaire

A total number of 97 physics students started the online survey, and of these, 85 completed the survey representing 87.6% completion rate. The remaining 12.4% incomplete responses were removed and not used in the analysis. The survey sample comprised students from two state schools, one integrated school and one independent (private) school. The distribution of the students' characteristics is presented in Table 22.

Table 22: Characteristics of Students' who responded to the Survey

Characteristic		Freq.	%
Gender	Male	53	62.4
	Female	32	37.6
Age (in years)	15	8	9.4
	16	30	35.3
	17	39	45.9
	18	8	9.4
Ethnic background	NZ European	58	68.2
	NZ Māori	3	3.5
	Pasifika	7	8.2
	Others	17	20.0
Level of study	Year 12	35	41.2
	Year 13	50	58.8
Type of school	Co-educational	67	78.8
	Girls only	10	11.8
	Boys only	8	9.4
Authority of school	State	37	43.5
	Private	38	44.7
	Integrated	10	11.8

The student sample comprised 35 (41.2%) Year 12 and 50 (58.8%) Year 13 students, with 35 (62.4%) being male and 32 (37.6%) being female. There were approximately equal numbers of students from state and independent schools. Only about 12% of students from the integrated school participated in the survey. The majority (68.2%) of the students who participated in the

survey were of NZ European background, only a few (about 4%) were of NZ Māori background. The mean ages of the respondents were 15.8 years for Year 12 and 17.1 for Year 13.

Physics Classroom Interactions – Students’ Perspective

This section reports the findings of the physics students’ responses to the rating-scale items on teaching approaches, teacher feedback and guidance and ICT usage in physics teaching. These responses were intended to answer research questions three, five and six. Likewise, the questionnaire asked students to indicate on a five-point Likert scale (with extreme alternatives of Never - Always) how often a number of teaching strategies and practices occur in their physics classrooms. Students were also asked to indicate how often they would like these strategies and practices to be applied.

Teaching Approaches

The findings in Figure 12 show that students generally agreed with the teachers on many points about how often the teaching strategies and practices were applied. Students’ conceptions match with the teachers’ report that instruction is teacher-centred. For example, students had few opportunities to plan and carry out their own experiments. Teaching and learning was more teacher-centred than student-centred. An examination of students’ experiences in relation to what actually happened in their classroom and how often they would prefer the strategies to be applied reveal that students were generally dissatisfied with many of the teaching approaches used. Students wish that instruction was more student-centred.

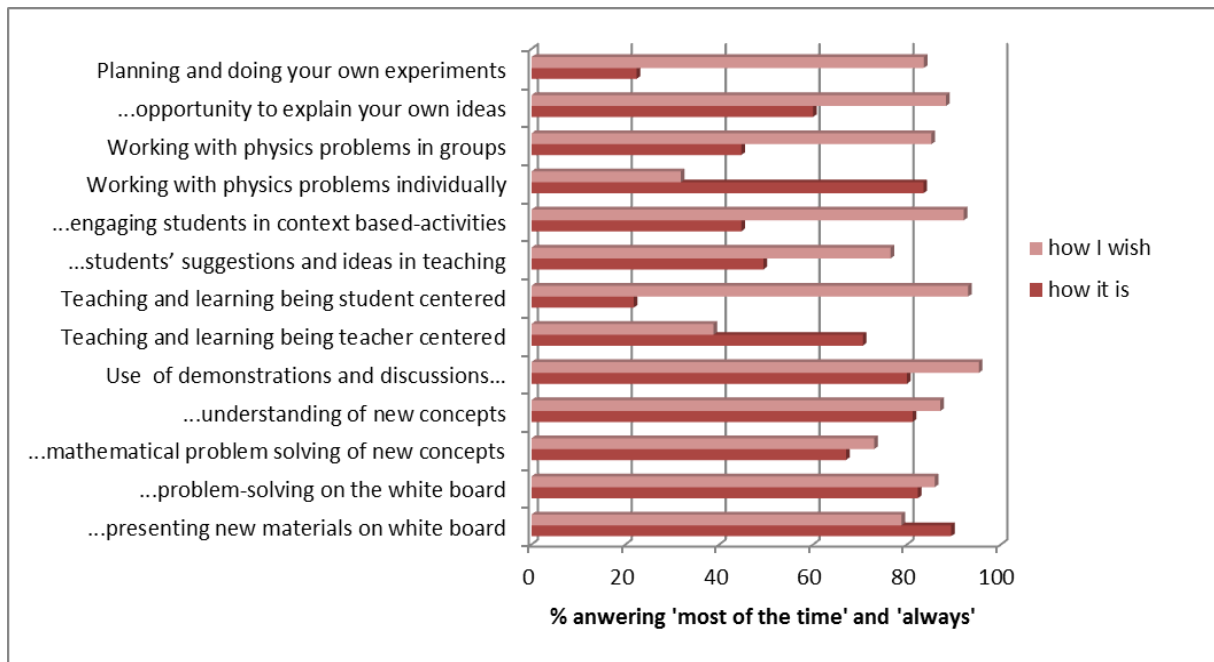


Figure 12: Students' responses about teaching approaches

Teacher Feedback and Guidance

The teacher feedback and guidance sub-scale was used to find out how physics teachers related to, encouraged, motivated and showed interest in their students' learning. Figure 13 shows that 3 students agreed with the teachers for almost all of the items on the teacher feedback and guidance sub-scale. The majority of the students (84%) indicated that their teacher's use of language was easy to understand. About 75% also stated that teachers often showed them how new concepts related to what they had done already. The students perceived that teachers did not talk to them about how they were getting on in physics as often as purported by the teachers. It was the wish of the majority (92%) of the students that teachers showed interest in their learning by having discussions with them about their performance in physics. The majority of the students (about 90%) would also like to have formative types of assessment in the classroom so that they can assess how they are performing in the subject.

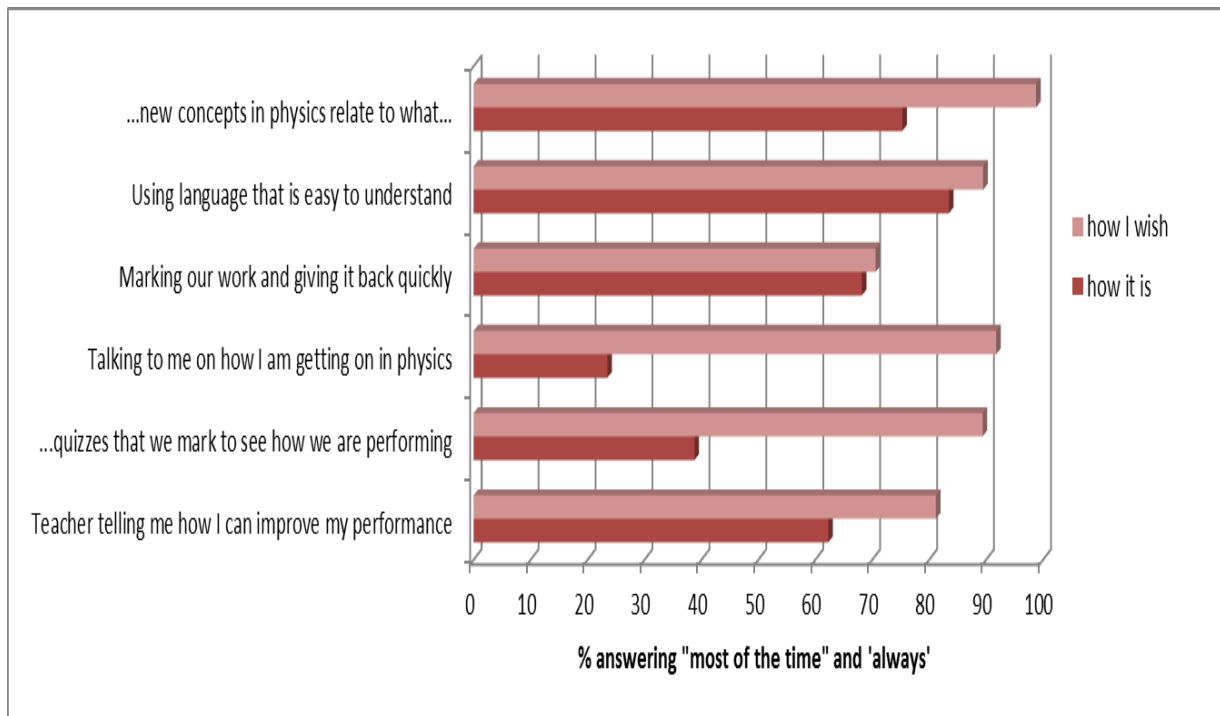


Figure 13: Students responses about teacher feedback and guidance

ICT Usage in Physics Teaching

The third sub-scale, ICT usage in physics teaching, was used to find out how often physics teachers use ICT tools to enhance student learning. As shown in Figure 14 students in the survey confirmed that ICT tools were rarely used in the teaching and learning of physics, as reported by the teachers. Looking at the differences between “how it is” and “how I wish” for the usage of ICT tools, it can be said that students were generally dissatisfied with the current situation. A change in teaching practice to include more use of ICT tools in the teaching of physics thus seems desirable.

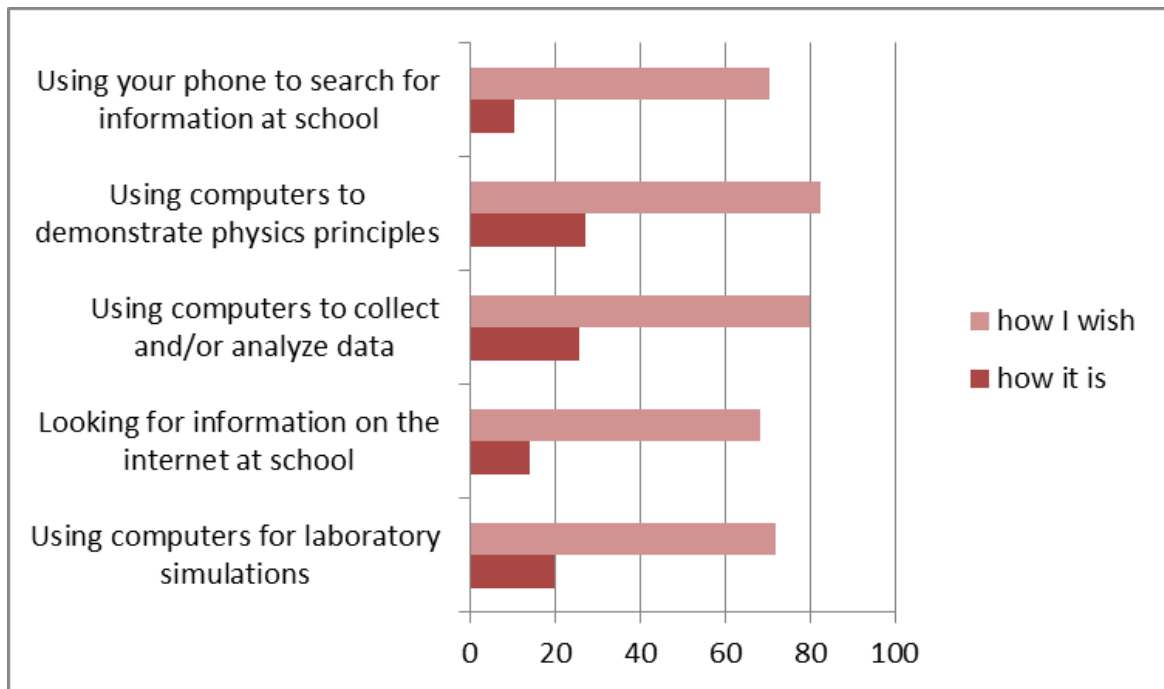


Figure 14: Students responses about ICT usage in physics teaching

CHAPTER 5

QUALITATIVE RESULTS

In this chapter, the findings gathered from the interviews and observations are presented. The results are presented in relation to the research questions that were formulated to guide the study. The discussions and implications of the findings are presented in chapter six.

Physics Teachers' Initial Teacher Education Programme

This section is focused on the main findings relating to the course content, course structure and programme requirements of ITE programmes for aspiring physics teachers in New Zealand. The section reports on the main similarities and differences of the ITE programmes offered to would-be physics teachers at three universities in New Zealand. For the purpose of anonymity, the three institutions were given pseudonyms as University A, University B and University C respectively. Data for this report were gathered from documents and teacher educators from these institutions who were coordinating the physics education programmes. Findings presented in this section were used to address research question one.

Teacher Educators' Characteristics

The general characteristics of the teacher educators in the three universities and the average numbers of physics teachers trained (ANPTT) per year are presented in Table 23. All three physics teacher educators were male and had specialised in a science discipline. The teacher educator at University A had specialised in physics and his counterparts at University B and University C had their specialities in chemistry and biology respectfully. The teacher educator at University B had significant physics content in his doctoral degree. The teacher educator at University C also indicated that he had undergraduate physics in his qualifications and had taught the subject

(physics) at high school, so had comprehensive knowledge of the curriculum and of the material to be studied. Whereas the teacher educator at University A coordinated only the physics education course, the teacher educator at University B coordinated the chemistry, physics and science courses of the graduate diploma secondary programme. The teacher educator at University C was responsible for the teaching of biology, chemistry and physics education courses. As can also be seen from Table 23 the average number of physics teachers trained per year from the three institutions ranged between three and seven. Further descriptions of the three teacher educators are presented below.

Table 23: Teacher Educators' Characteristics

Characteristics/institution	University A	University B	University C
Gender	Male	Male	Male
Educational qualification	MSc(Sci. Educ.), BSc, BA, Dip Tchg	PhD (Chemistry), BSc (Hons), Dip Tchg	MSc (Ecology), Grad Dip Sci., BSc
Teaching experience	23 yrs as teacher educator	6 yrs as teacher educator, 10 yrs as teacher in schools	13 yrs as teacher educator
Responsibilities	Coordinates physics education programme	Coordinates chemistry, physics and science education programmes	Coordinates biology, chemistry and physics education programmes
ANPTT per year	4 and 5	6 and 7	3 and 4

The teacher educator at University A joined the university in 1991 after 13 years teaching physics and junior science at high school. His professional interests included the nature of science, effective teaching of physics and physics education research in general, curriculum and resource development in secondary school physics and school electronics and electronics education. In 2001, he was awarded a Bronze Science and Technology Medal for an outstanding contribution to curriculum, professional and resource development in science education, with particular regard to physics.

The teacher educator at University B joined the College of Education as a Lecturer in Science Education in 2008. He had worked as a scientist for many years before qualifying as a teacher. He had experience teaching science for both the National Certificate of Educational Achievement (NCEA) and the International Baccalaureate (IB) Diploma. He was a teacher in schools for more than 10 years and a Head of Department, teaching mainly chemistry and physics before joining the university. His fields of research included health and safety in science, ICT in science teaching and learning, innovative pedagogy and teacher education.

The teacher educator at University C had almost 30 years of experience as a classroom teacher, Head of Science Faculty, and acting Associate Principal in a range of New Zealand secondary schools. He was national programme manager for ecological management training in the Department of Conservation for four years before being involved in education research and teaching in pre-service science education. His research areas included how ecological science is taught in New Zealand primary and secondary schools, evaluating equity and diversity in pre-service education programmes and studying the effectiveness of pre-service science education courses in preparing student teachers for professional practice.

Structure and components of ITE physics programme

The ITE physics programme offered by the three universities is a one-year full-time programme which runs from February to November. The main structure, components and programme requirements are summarised as follows.

The course structure and programme requirements for physics ITE programmes are generic across the three institutions. The course was one semester in length with two-seven week periods of teaching practice (practicum). To a considerable extent the course structure had been set up to meet the requirements of the New Zealand Teachers Council for initial teacher preparation for secondary teachers. The programme requirements to teach physics and therefore entry into the course were Stage 3 physics papers and general science education papers. During the interview, the teacher educators explained that, with regards to programme entry requirements for engineering students and foreign students, they looked at the applicant academic transcripts to decide whether the applicant had a sufficiently strong physics background to pursue the physics course. The teacher educator at University A stated that he did not admit people with only Stage Three Electronics papers but looked for papers with a stronger core component of physics, such as Stage Three Mechanics or Civil Engineering as preparation for entry into secondary teaching.

The components and nature of the programmes, varied considerably across the Colleges of Education at the three universities. Analysis of the interviews revealed that the teacher educators, who were also the coordinators for the physics teachers' ITE programme solely determined the component content to be included in the physics teacher education qualification. Analysis of documents gathered indicated that there was no national teacher education curriculum to follow in terms of subject matter content knowledge or pedagogical content knowledge (PCK) to be included in the qualification. Each teacher educator had designed his own course work for the programme which they reviewed as and when necessary. The physics educator at University A,

for example, commented that he was reviewing the course to include a session that would take into account the interest and special needs of ethnic groups with special interest in Māori students. He explained below:

Each year I review the course, and at the moment I'm wanting to include a bit more relation or thinking about students from various ethnic groupings such as Māori, so that when students complete assignments they take into account the interests and special needs of in this case Māori students, being our Tangata Whenua of New Zealand (Physics Educator, University A).

The teacher educators at University B and University C indicated that they regularly contact local physics teachers in schools to keep themselves abreast of issues relevant to their course and they make changes to their courses as and when required.

It is not the intention of this study to highlight what each teacher educator was doing but rather to discern whether the preparation that pre-service physics teachers received was sufficient and appropriate for the classroom. The pre-service physics teacher educators were clear that their ITE physics courses were primarily about PCK, and that the non-education or first degree that students undertook was assumed to provide most of the subject knowledge required. The physics educators stated that some of the students who enrolled in the physics courses were weak in some areas of physics content knowledge, but there was little time available to address this because the courses were not intended to teach the students physics content but to equip them with pedagogical knowledge to teach physics. The physics educator at University B mentioned that he occasionally spent some time developing content knowledge. He stated:

The students that come to the physics course are often quite rusty in terms of content knowledge, and that's a concern and the comment has been made in

the past by associate teachers in schools that the students need to better know their physics. They don't come to our physics course with the intention of learning physics, we want to teach them to be physics teachers. But we invariably end up spending some time looking at content. (Physics Educator, University B)

The physics educator at University C stated:

We spend time looking at the curriculum statements and NZQA requirements for the NCEA levels, particularly Levels 2 and 3, so they become very familiar with the material that's supposed to be taught. Where there are gaps in their own knowledge we give them time and resources and they interact with each other to try and fill those gaps. But there's not an emphasis on trying to actually remedy any changes in their subject content knowledge. (Physics Educator, University C)

The physics educators emphasized that students came into the physics courses (and other science courses) with fairly specialist degrees which are supposed to provide the content knowledge required and there may be big gaps in content knowledge across science areas more generally. But what they seemed to be doing was mainly focussing on NCEA content and different pedagogical approaches to teaching this content. Responsibility for learning content was mainly given to the aspiring student teachers to remedy any gaps in their subject matter content knowledge.

Approaches to Assessment

In this section, the findings about how the pre-service physics teachers were assessed in their physics education course are highlighted. Analysis of the teacher educators' interviews revealed

that the pre-service teachers were assessed through a variety of assessment tasks. These are described below.

The teacher educator at University A explained that students undertook three assessment tasks spread over the course. The first assessment task, which was worth 20% of the physics education course mark, required students to complete a computer aided resource for teaching Year 12 or Year 13 physics. In this task, students were required to produce student instructions, the resource itself, and written teacher notes that explained to other teachers how to use the resource. They were also expected to write about how the resource could fit into a teaching programme; where it could be placed; strengths and weaknesses; and extension work that could be included. The second and the major assignment task was to scope out a topic, in either Year 12 or Year 13 physics. In this task, students were expected to research the topic and draw a flow diagram of how that topic could be taught. In addition, they were also to select an experiment that related to the topic, trial it, and modify it to suit the concepts to be taught. This assessment task was worth 60%. The teacher educator mentioned that due to the small number of students in the class, he always made sure each student did a different topic so that they could share their assignments. The third and final assessment task which was worth 20% was a one and a half hour test at the end of the year. The teacher educator stated that he usually gives students a selection of Level One, Two and Three exams from the NCEA physics questions from previous years. According to him, students sit this test to demonstrate the content knowledge they know so that he could recommend them to prospective employers that contacted him.

Similarly, the physics educator at University B indicated that, there were three assessments in the physics education course – the planning and preparation of a physics unit of work, readings on physics teaching pedagogy and the preparation and presentation of a physics practical demonstration. He explained that the unit of work involved preparing and resourcing a sequence

of lessons that the aspiring teachers could use when teaching in a high school. The set of lessons covered both theory and practical components of the physics topic. The second assessment task was a collection of readings about the PCK of physics teaching, including recent research on pedagogy. An example of such a reading, which the previous year group did, was about energy and the misconceptions associated with energy. A set of on-line quizzes based on the readings were designed to test students on what they had read. A practical demonstration was the third assessment and this required students to prepare and present a practical demonstration on some aspect of school physics to their peers. Students were required to address all necessary health and safety considerations associated with their practical demonstration. An example of a recent student demonstration was the construction and operation of a cloud chamber to view alpha decay. In addition to these three main assessments, the prospective student teachers reviewed past NCEA examination papers for physics and completed three of these exam papers which were marked by their peers. The physics educator at University B stated that there was no examination at the end of the course, and students had to pass all the assessments tasks.

To start with, the teacher educator at University C reiterated that there wasn't a physics education course as such, and that there was a combined class for biology, chemistry and physics. He indicated that within the general course there were two assessment components which were quite specific. The first component dealt largely with planning a couple of lessons and better approaches to teach. This required each student to work within their subject area. That is, students that came into the course with a physics background would plan a sequence of physics lessons, and better approaches to teach these to the class. Thus, they would try and teach their class mates a physics concept. The second assessment was an end of year examination, a three hour science paper for all students. The teacher educator explained that most of the three hour science paper

was generic science, but there were always two questions in each exam, specific to NCEA in physics or chemistry or biology for students to select.

Asked how each teacher educator felt about his assessment approaches, they all indicated that they were happy with what they were doing but open to other possibilities. The major challenge reported by all the three educators was the limited amount of time to prepare students for their practicum experiences. One teacher educator commented:

It's always hard to get them to a stage where they're going to be teaching physics in a school, because I see them for four or five weeks and then they begin practicum. And they may well have a senior physics class and we may not have addressed part of the course that they're teaching and that's always an ongoing issue. (Teacher Educator, University B)

The Case Studies

The purpose of the case studies was to gain more insight into teaching and learning practices that occur in the physics classrooms in schools. Four exemplary physics teachers (three males and one female) from four secondary schools (two state schools, one integrated school and one independent school) in Christchurch voluntarily participated in the study. The teachers were identified and selected with the help of science advisors at UC Education Plus. Information sheets and consent forms were given to the principals of the selected schools to seek their permission (Appendix B) to allow their school and the physics teachers to participate in the study. Similar information sheets and consent forms were given to teachers and physics students who participated in the study (Appendix B).

Information about the teachers and their schools are presented in this thesis using pseudonyms in order to conceal their identities as indicated in the information sheets and consent forms. The

following pseudonyms were used: Philip of School A, Nick of School B, Vicky of School C and Bernard of School D. The findings from all the cases are presented in the following sections.

A total of at least eight routine observations (both Year 12 and 13) were prearranged, however, some observations were missed due to school activities such as students' internal assessment activities, teacher professional development workshops and teacher-only day events. This resulted in different numbers of observations being completed for each teacher – eight for Philip; eight for Nick; nine for Vicky and six for Bernard. With the exception of Philip, almost all the lessons observed lasted between 50-55 minutes. Philip had double periods for each class and so these observations lasted 120 minutes. A short meeting was held with the teachers after each lesson and during this time the teacher completed a self-reflection checklist. The teachers' scores for this checklist were matched with the score given by the researcher and any differences were reconciled.

Case Study Settings

School A was a co-educational school state school. Its decile rank falls within the decile band classification of 1-3. There were 27 senior secondary classes (Year 12-13) in the science-maths stream with an average number of 19 students in each class. The school had a student population of 745 with a total of 53 teachers, of which eight were science teachers. Of the science teachers, only one was a physics teacher. The school had one part-time science technician for all the science classes and this person was employed for 20 hours per week. School A had five laboratories for 32 classes (both senior and junior science classes) at the time of the study – it had lost some of its classes due to a falling roll after the Christchurch earthquakes.

School B was an all-male state school with a student population of 1350. Its decile rank was within the decile band classification of 8-10. There were about 60 senior classes in the science-maths stream with the average number of students in each class being 28. The school has a total

of 88 teachers of which 15 were science teachers, three of this number were physics teachers. In addition to this was one part-time physics teacher. There was one full time science technician available for the science classes. Though the laboratory facilities were adequate, they reflected that they were aged, as indicated by the physics teacher.

School C was a state integrated all girls' school of decile band ranking 8-10. The school had a student population of 738 and 32 senior classes in the science-maths stream with an average number of 22 students in each class. There were a total of 50 teachers, six of whom were science teachers, with no full time physics teacher. The school had one part-time physics teacher who worked 15 hours per week. There was one part-time science technician for all of the science classes who was available in the mornings. Teaching and learning facilities for physics were described as adequate by the physics teacher.

School D was a private (fully independent) co-educational school for pre-school to Year 13 students. The school was ranked within a decile band of 8-10 and had a student population of 940 at the time of the study. The school had 40 senior classes in the science-maths stream with an average number of 20 students in each class. The staff comprised 75 teachers, 12 of whom were science teachers. The school had two full time and one part-time physics teachers. There was also one full time technician available for the science classes. Facilities for supporting teaching and learning of physics in particular, were described as more than adequate by the participant teacher. School D was purposefully selected as an additional and alternative case study. Bernard, the physics teacher at School D, was a biologist who had taught biology for almost ten years but then switched to physics and had been teaching physics for the last 25 years of his career.

The next sections provide detailed descriptions of the individual case studies. The four case studies were organised under sub-headings which were used to address the research questions. The sub-headings are related to the research questions as follows: Using the Observation Checklist

(Research Question 3); Conceptions about Teaching (Research Question 2); Classroom Practices – Teaching Approaches (Research Question 3); Factors Constraining the Quality Teaching of Physics and the Low Numbers (Research Question 5); Ways for Improving Physics Teaching and the Numbers Involved (Research Question 6); Professional Learning Experiences (Research Question 4); Findings from Students' Focus Group Interview (Research Questions 3, 5, & 6); and Why Students would or would not Become Physics Teachers (Research Questions 3, 5, & 6).

The Case of Philip

Education Background and Experience

Philip was a physics teacher in School A. He was aged 50+ years and had 30 years of teaching experience. Philip retired from teaching soon after participating in the study. His teaching load per week was four hours of Level 3 (Year 13) physics, four hours of Level 2 (Year 12) physics, four hours of Electrotechnology, four hours of Level 1 (Year 11) Science and two hours of Year 10 Science. Philip was the Assistant Head of Science and the teacher in charge of physics and Electrotechnology. He holds a degree in physics and a Graduate Diploma in Education. Philip became a physics teacher through a scholarship scheme that was instituted specifically for the training of physics teachers due to a shortage at that time. The financial reward was a factor in his decision to enter teaching.

After my first degree I travelled around for a while and later ended back in the country (UK) and was working as a Postie. At that time they had a scheme to encourage mature graduates into physics because there was a shortage (1979), and so I was offered more money to train as a teacher than I was getting as a Postie so I did. (Philip)

Philip was observed eight times teaching physics to his senior classes – four at Year 12 and four at Year 13. He was interviewed after the observations.

Using the Observation Checklist

As described in Chapter 3, the instrument (RTOP) was divided into five sub-scales, with 25 observable items in total. Each sub-scale has five items and each item on the scoring sheet was rated on a scale from 0 to 4. An item was scored “0” if the characteristic never occurred in the lesson. The item was scored “4” if the characteristic was very descriptive of the lesson. Summing

the 25 item scores for the sub-scales results in a lesson score ranging from 0 to 100, this describes the degree of reformed (good) teaching present (MacIsaac & Falconer, 2002; Sawada et al., 2000). Philip's average scores for the various sub-scales are presented in Table 24.

Table 24: Philip's Average Scores on the RTOP Sub-Scales

RTOP sub-scale	Average score (out of 20)
Lesson Design and Implementation	12.8
Propositional Knowledge	15.5
Procedural Knowledge	13.5
Communicative Interactions	14.8
Student/Teacher Relationships	14.9
Total	71.5

The scores in Table 24 showed how Philip's teaching was rated. Philip had an average total score of 71.5. This figure is greater than 50 and therefore represented considerable presence of good pedagogical practice. His lowest score was 12.8 (out of 20) for the Lesson Design and Implementation sub-scale. This sub-scale was intended to identify recognition for student preconceptions and knowledge; the fostering of a learning community; exploration before formal presentation; the seeking and recognition of alternative approaches; and inclusion of student ideas in classroom direction. Data from eight observed classroom lessons on mechanics showed that student exploration rarely preceded formal instruction. In addition, the focus and direction of the lessons was predominantly teacher directed. Philip on the other hand, obtained relatively good scores on Propositional (Content) Knowledge and Classroom Culture – Communicative Interactions and Student/Teacher Relationships.

The lessons generally started with Philip introducing the topic for the day and reviewing student knowledge about what had previously been done on the topic. Students would then undertake the tasks/activities designed by Philip for the lesson. Some of these activities included practical work, exercises from work/text books and problem-solving on the white board. Philip always ended his lessons with a summary of the day's activities through questions and answers, and the giving of homework. Details of Philip's teaching and post-lesson interview are described in the following sections.

Conceptions about Teaching

The analysis of the classroom observation data and Philip's interview revealed that he held two main conceptions about teaching: "getting students' engaged" and "establishing a good relationship with students". It was evident that these two conceptions originated from his initial teacher education programme and had been consolidated during his 30 years of teaching experience.

Getting students' engaged. According to Philip, the most effective learning occurs when students are highly engaged. He contended that it doesn't really matter what else you do, if students are engaged you can do practical work, you can conduct discussions, you can argue, you can debate, and many other things.

If they're engaged they're going to learn, and so it's all about getting student engagement. If they become engaged, you can do practical work, you can do problem solving, you can do investigations, you can do discussion, you can do sometimes just an occasional lecture, and you can do anything you like.

(Philip)

This conception of teaching that Philip had was instigated by his course instructor during his teaching qualification programme. His course instructor was a believer in practical work and learning by inquiry, and never liked the idea of students copying notes from the board. As a student, Philip was made to believe that it was a waste of time to just copy mindlessly off the board. Thus, he formed his conception of teaching being about getting students' engaged with the purpose of arousing their interest and also keeping them busy, working and solving physics problems.

Establishing a good relationship with students. In addition to having students' engaged, Philip also believed that students are more motivated to learn if they have a good relationship with their teacher. He thought that a good student-teacher relationship is vital because students would be more willing to ask questions to clarify lesson content that they found difficult to understand. Philip's relationship with students was demonstrated through his demeanour in the classroom and how he related to the students. Philip would sometimes sit by a student and/or group of students and provide individual and group assistance as and when necessary. In one of the lessons, four students who were absent from the previous class were taken to the back of the room where Philip discussed the previous lesson with them while the other students worked individually on a given problem.

Classroom Practices – Teaching Approaches

The conceptions Philip had about teaching influenced his teaching approaches. Further analysis of classroom observation data showed that Philip used a variety of teaching methods to engage his students. He set up practical demonstrations and lessons for students, he sometimes lectured, he provided detailed explanations and examples of physics problems on the white board, and he played videos and used interactive demonstrations as and when necessary. Though these teaching methods characterised his lessons, the predominant instructional methods were lecture

and problem solving. These most of the times involved Philip giving a question to students – sometimes he put the question on the board, at times he verbalised it, and following a period of teaching, he asked students to solve questions from their workbook. The questions were occasionally discussed together in class but most of the time they were not.

Asked why he used these methods and how effective he thought they were, Philip argued that particular instructional methods are effective in particular situations, and to him, his lessons are characterised by a mixture of methods, an assertion classroom observations attested to. He often linked physics concepts to real-world situations. For example, an educational visit was undertaken to a playground in the community where the concept of “angular momentum” was demonstrated using a “merry-go-round”. Also, when teaching the concepts of change in momentum and impulse, Philip and the students had a practical demonstration on the school field, outside the classroom. Students were paired and given at least two eggs of the same mass. In turns, each egg was thrown from a distance with the same velocity by one student while the other student tried to catch the egg with a spread sheet. The egg hit the ground and broke if a student was unable to catch it. When the class was reconvened in the classroom, Philip led a discussion on the demonstration and guided students to explain the differences in the results with regards to the stopping force exerted by the spread sheet and the ground. To further explain the concepts, Philip played a 15 minute video on car crashes and mentioned that the same concept applies to automobiles. Students were extremely excited and reflective of their learning.

The lessons observed could be put into two groups – practical and non-practical lessons. In practical lessons, students had enough time to carry out investigations and write a report. This was a consequence of the fact that Philip had a double period for each lesson which lasted for 120 minutes. During practical lessons Philip spent most of his time walking around and providing guidance to students. Practical activities were most often carried out in groups of three and four.

Even though students in Philip's physics classroom were encouraged to do practical work, most of the time this involved students closely following teacher instructions. The practical lessons did not encourage students to generate alternative strategies for investigating or problem solving because students were often given instructional sheets which had a list of apparatus, the procedure to be followed and a diagram of the experimental set up. This contradicted what Philip indicated on the questionnaire that students most of the time plan and do their own experiments. Likewise, the results of the practical work or interpretation of the findings were often not discussed at the end of the practical work. After the activity, students would resume their seats and individually present and discuss or interpret the results on a worksheet. The worksheet was then attached to their workbook and submitted to the teacher before the class ended.

Most of the observed non-practical lessons involved fundamental concepts of physics and Philip had a solid grasp of the subject matter content knowledge. This was evident in the type of questions he asked and how he responded to students' questions. Both Philip and the students were most of the time asking "why" questions, which required the students to think and articulate their thoughts. Students' performing set exercises, copying notes from both the white board and PowerPoint slides were prevalent in the non-practical lessons. Philip also placed an emphasis on collaborative learning by encouraging students to work on physics problems in groups. Most of the time, he asked students to work in groups of three or four while solving physics problems. Students with different abilities were normally grouped together and were encouraged to help one another. Students were also encouraged to participate and communicate their ideas to one another and there was a climate of respect for what others had to say. However, on some occasions students worked individually on a given activity/problem.

Despite a high proportion of student talk and participation in Philip's lessons, physics problems were sometimes verbally given to students to work on and in some cases, these questions

were not discussed together in class. Philip was criticised for this by a group of his students who were later interviewed. Again, there wasn't any evidence to suggest that Philip supported literacy development within his teaching. He disagreed with the proposition that physics teaching involves some degree of literacy (both written and mathematical literacy) and maintained that, although mathematics in particular, is a prerequisite for studying physics, it should not need to be developed while teaching physics.

... one assumes when the students are doing physics that there is a certain degree of literacy, both written and mathematical literacy which um, sometimes is a wrong assumption, especially with the mathematics which is a prerequisite to study physics. So many students come through with very limited mathematical skills and that is a drawback in physics... it definitely is. (Philip)

Factors Constraining the Quality Teaching of Physics and the Low Numbers

Philip had a strong belief that physics teaching had always been enjoyable but felt other demands on his time had reduced his focus on improving teaching and learning. He asserted that throughout his entire teaching career, the introduction of internally assessed achievement standards and the alignment of the standards with the curriculum were two of the major factors limiting the quality of physics teaching. He indicated a belief that the introduction of internally assessed achievement standards demanded an enormous amount of time for teachers to understand and implement. In addition, the alignment of the achievement standards with the curriculum, where some of the assessment was shifted onto teachers, appeared to have increased his (and physics teachers') work load and hence reduced the time available to spend on physics teaching and improving upon the better approaches to teach physics lessons.

Some of the assessment is being shifted onto teachers so we now do two internal assessments as opposed to the one internal and four externals. Running an internal assessment is hard work, you have to get it right and it takes time and energy to get it right. So all these demands have reduced the amount of time that I can actually spend on physics and improving upon the better approaches to teaching. (Philip)

Philip further explained that the idea of using teacher-made tests for internal assessments was not as easy as he (and other physics teachers) thought. He suggested there was a missing link somewhere.

... the rationale was, oh well, will give class tests anyway, it's not as simple as that because with the NZQA assessment you have to get it right. You have to get the assessment schedule correct, you have to make sure that the test is at the correct standard and assessing the correct standard. You have to go through all the rigmarole of moderation and everything else, so it's time and energy consuming. (Philip)

He further mentioned that NCEA has dominated physics education for the past 10 years, i.e. implementation, moderation, changes to standards and alignment. Philip felt this had decreased the emphasis on the quality teaching of physics.

Another constraining factor mentioned by Philip was student progression through the NCEA levels. He believed that success was required at the lower levels before students could master the more challenging higher level content

Physics does require prerequisites. It's very unusual for a student who hasn't done well at a previous level to succeed at the next level up, for example, at Level 2, if they haven't succeeded at say mechanics at Level 1, the chances of achieving Level 2 is relatively small. (Philip)

Philip called for improved teaching of physics at junior level, especially during Level 1 Science. He also considered that mathematics was a problem for many students. He pointed out that students often found simple mathematical operations, like rearranging equations, quite difficult and added that in the past he had organised remedial maths classes for students (at no cost), but due to the current demands on his time he was now unable to continue doing this.

Ways for Improving Physics Teaching and the Numbers Involved

“Reduce the number of assessment changes, provide more professional learning opportunities for teachers (but not more on assessment), ensure physics teachers are adequately resourced”; these were the answers Philip gave when responding to a question which sought his views on how physics teaching could be improved. Philip lamented that the NZQA assessment system had certainly been onerous over the past years and a major hindrance to the quality teaching of physics. He suggested that if only one thing could be changed it should be the reintroduction of a single internally assessed achievement standard to replace the current two assessments.

Philip compared the teaching resources now at his disposal with those he had at his previous school in the UK. He considered the current resources to be much less suitable and he described as “very unfortunate” the provision of one part-time science technician to support his department, contrasting this with the three full-time technicians provided in the UK. He consequently called for better quality teaching resources and support and improved ICT facilities. Philip's comments on professional development are presented in the next section.

Philip maintained that if the status and remuneration of teachers, and of physics teachers in particular, were improved, more physics graduates might consider teaching as a career. He observed that physics graduates have many career choices available to them and some of these have higher status and are better paid than teaching.

If you're a physics graduate I imagine that the opportunities are many and varied and the opportunity to make more money in a more fulfilling job is there if you've come out with a physics degree. For example, I know that the banks are now recruiting physics graduates in the UK. I don't see that teaching can compete as a career with some of these other things. (Philip)

He wondered why after 30 years this problem still persists.

... but I mean, this was a problem thirty years ago in the UK because it's exactly why I became a teacher. There was a shortage of physics teachers and so they offered what they called mature scholarships to train. So thirty years later nothing's changed. (Philip).

Professional Learning Experiences

While discussing ways to improve physics teaching and learning, Philip highlighted the need for professional development opportunities for teachers. He had participated in numerous professional development experiences within the last five years. Philip had this to say:

In physics, I've only had one professional development opportunity in the last twelve months and that was a course run by UC Education Plus, and it was on literacy in senior physics and I've got to say that I didn't find it particularly useful. I did not find it useful at all, and I was quite disappointed. But in the

last twelve months I've had lots of professional development here at school but it's mostly about Junior Science. No (external) professional development, apart from that one on physics. (Philip).

Philip considered professional development he had initiated himself to be especially valuable. He had undertaken self-study on teaching as inquiry to understand his own teaching practices, analysing tests, exams and experiments to find better ways to help students with their learning.

I do my own professional development. I'm always looking at different experiments, different ways to present material, and I'm always analysing tests, exams to see if there's a better way to get the ideas across. I'm doing that constantly, and all the time. For example at the moment I'm looking at a way, a better way to measure Planck's Constant using LED's because in the past we've done it with the photoelectric effect. Though it gives a good result, there is another way that I've discovered with LED's. (Philip)

Philip believed that this form of professional learning was far more effective than other professional development approaches. He indicated a preference to spend more time doing this rather than attending workshops, which he claimed would be of little use to him since they seemed to focus predominately on assessment.

Findings from Philip's Students' Focus Group Interview

There were a total of 30 senior physics students (twenty Year 12 and ten Year 13) in Philip's classes. Originally, the researcher had planned four focus groups to interview 20 students, by selecting 10 from Year 12 and all the Year 13 students. However, all the students indicated their willingness to be interviewed and no one wanted to be excluded, hence six focus group interviews

were organised to interview the entire class. The students' focus group interview was intended to gain greater insight into the students' thoughts and feelings about the teaching and learning of physics and changes that might make physics more interesting to learn.

When asked the question: "Do you enjoy physics lessons and what makes you enjoy or not physics lessons?", the majority of the students (70%) said that they enjoyed physics lessons and found physics interesting and fun because it was relatable to the real world and they were able to find out how things work. However, they were clear in their views that sometimes the lessons were pretty dry and that made the subject boring. About 20% of the students also stated that they enjoyed physics lessons only when they understood what was been taught, otherwise they got confused in the class and didn't really like it. Only a few (10%) indicated that they didn't particularly enjoy physics lessons because the content was too hard for them.

I really enjoy physics at the moment. I think our teacher goes at a good pace,

I can sort of keep up and understand what's going on. (Boy, Year 12)

I enjoy the lessons most of the time because he (Philip) makes them interesting with examples and relates it to real life things...I find that better to learn. (Girl, Year 13)

Although the majority of the students enjoyed physics lessons and the teaching approach, some of the students in the focus group interview were unhappy about physics questions being given to them only verbally by the teacher (Philip). They were also unhappy about the fact that most of the time they did not get the opportunity to discuss questions together. They would like the questions written on the board and sometimes the solutions as well so that they could copy and understand it later.

I enjoy the way he's teaching currently, by giving us a question, but sometimes when he just says it verbally, I don't get it and he doesn't write it on the board so I just leave it, which kind of annoys me, I would like him to maybe write it on the board and also go through the solution with us so I can copy it down and understand it later. (Boy, Year 13)

Usually, most of the time he tells us or puts a question on the board expecting us to know how to do it, which can sometimes not work because we don't know how to do it, so...(Girl, Year 12)

On how they would like their physics teacher to change his teaching style or make physics more interesting to learn, almost all of the students indicated that they would like the teacher to write the questions on the board. They also wanted a whole class discussion on the board questions as well. They also voiced the opinion that the teaching was most of the time dry and that this made the subject boring, and they proposed more group activities and discussions so that they could interact with and learn from their peers. Students also wanted more practical and hands-on activities, they saw this as more fun and interactive, thereby making physics more interesting to learn.

I think more group activities and classroom discussions so that we could work off each other's strengths and weaknesses to achieve better results in the class.

(Boy, Year 13)

Another area where students wanted to see a change was the mathematical aspect of physics. Students would like their teacher to do more on the mathematics rather than assume they (the students) already know and rushing through the mathematics.

He should do a bit more on the mathematics...he's just like, oh it's mathematics, the rest is algebra... from here on put your values into the equation... and that is it. (Girl, Year 13)

Another student also indicated:

He assumes that we already know the mathematics which we don't, so maybe, just pretend he's teaching retards...teaching dummies like instead of, oh you know, and you know that...(Girl Year 13).

Some of the students in the focus group also gave an impression that physics was often not taught at the junior level and hence wanted physics started at the early stages so that they would have better preparation for senior physics.

Maybe if students started young, say when they came to Year 9 they started doing simple physics questions so that not just straight from Year 11 so that you've got a big base of your physics. (Boy, Year 12)

Why Students would or would not Become Physics Teachers

None of the 30 students interviewed in Philip's class would like to become a teacher in the future. About 70% of the students in the focus group articulated that they wouldn't take physics as a pure subject at university but rather preferred to undertake "physics-enriched" courses like engineering and health science because these lead onto good jobs and they are also more practical. The remaining 30% of the students did not want to pursue physics further or take any physics related courses. If teaching happened to be their last option, they would prefer other subjects, for example biology, to physics. Others said they would also prefer to teach at the primary rather than high school level.

I will definitely not, I'd rather be a bus driver or something. I don't, I get frustrated with people that don't know what I know so I don't think teaching would be the best option for me. (Girl, Year 13)

Another student also stated:

I probably wouldn't. If I did go into teaching I'd probably go into primary school teaching rather than high school. So I would definitely not be teaching physics. (Girl, Year 13)

This position by the students was not unexpected because there is evidence to suggest that their physics teacher (Philip) did not want them to become teachers. In the interview, Philip mentioned that (in his personal view) science in New Zealand is underfunded, has very little job security, has very little private investment and operates on the whim of whatever political party is in power at the time. Because of these reasons, he found it difficult to advise students to go into science. Even though he would advise his students to pursue physics further, i.e. for those students who would want to, he would urge them to go into engineering and medicine but not science per se, as illustrated by his following statement.

...so I try to steer students either into medicine or engineering. I wouldn't personally advise my own children, in fact I didn't advise my own children. I advised them to become engineers. (Philip)

The Case of Nick

Education Background and Experience

Nick was a physics teacher in School B and Head of Physics. He was aged between 41 – 50 years. At the time of the study, Nick was teaching 20 hours per week, although his normal teaching load for the year was meant to be 17 hours per week. He holds a PhD in Physics and a Graduate Diploma in Teaching and Learning and he has been teaching for about 12 years, in science and physics.

Nick decided to become a science and physics teacher while he was doing his postgraduate studies. He was a teaching assistant and was involved in teaching laboratories and tutorials at the university prior to undertaking his teacher education course. Eventually, he became the head teaching assistant with responsibility for the work of others, i.e. teaching demonstrators how to demonstrate in the laboratories. He enjoyed the teaching and consequently enrolled at the Christchurch College of Education, where he obtained his teaching qualification.

In the University, I was demonstrating labs for about twelve to fifteen hours a week. I actually liked the teaching, I liked the, particularly the moment when the student gets it...when they understand something that was difficult for them, even if it's a simple concept. And so I finished my degree, I finished my PhD and then went straight to Teacher's College. (Nick)

Nick added that there was a shortage of physics teachers at that time and so he was offered a scholarship to train as a physics teacher, which he accepted.

Despite the fact that he had a number of physics teachers and some made physics interesting to learn, Nick believed that his desire to become a physics teacher was not inspired by anyone. He emphasized that he always swore not to be a teacher, because he had two sisters and a brother who

were secondary school teachers. However, he just found that he liked the subject (physics) and decided to be involved with it. He attributed his success to his own personal interest and effort as he explained in the following statements.

I wouldn't say I was inspired by anyone, no, not in Science, not in physics. I got where I was by working hard, and getting through what I needed to get through. I did achieve that way, because I really liked physics and I always wanted to be involved in physics. (Nick)

At the College of Education, not only did Nick do courses in science, he also did courses in mathematics (Junior and Senior Mathematics) which equipped him to teach mathematics as well. Some of the key content he learnt during his teacher education included lesson planning, using formative assessment to guide teaching (which was then called reflective teaching), classroom management and voice projection. Even though he had done a lot of teaching up to that point and had some of those things in his skillset, Nick was still pleased with the ideas he learnt, especially the reflective teaching.

...but it was the reflective teaching, working out what worked well, what didn't work well and why it didn't work well, why it did work well, and learning from that. So that really was one of the key aspects of the programme. (Nick)

Nick was observed eight times teaching physics to his senior classes – four at Year 12 and four at Year 13. He was interviewed after the final observation.

Using the Observation Checklist

Nick's teaching was also rated using the RTOP checklist. Both Nick and I completed the observation checklist for each lesson. Both scores for each lesson were matched up and any differences were reconciled. The average scores for the eight classroom observation lessons are summarised in Table 25.

Table 25: Nick's Average Scores on the RTOP Sub-Scales

RTOP sub-scale	Average score (out of 20)
Lesson Design and Implementation	10.0
Propositional Knowledge	16.6
Procedural Knowledge	10.1
Communicative Interactions	11.3
Student/Teacher Relationships	13.1
% Total	61.1

As can be seen Table 25, Nick obtained an average total score of 61.1%. This score is greater than 50 and therefore gives an indication that there was a considerable presence of good pedagogical practice. Among the five sub-scales, Nick obtained a relatively high score (16.6 out of 20) for Propositional (Content) Knowledge. This sub-scale was intended to identify teachers knowing their physics and providing a lesson that: involved fundamental concepts of physics, promoted coherent understanding across topics and situations, demonstrated teacher content knowledge, encouraged appropriate abstraction and explored and valued interdisciplinary contexts and real-world phenomena. Data from eight observed lessons on Electricity and Magnetism showed that Nick demonstrated understanding of subject matter content knowledge. In addition, the lessons

involved fundamental concepts and at times, he made connections with other disciplinary knowledge and ideas as well as real life examples.

His lowest scores were 10.0 (out of 20) and 10.1 (out of 20) for Lesson Design and Implementation and Procedural Knowledge respectively. Among other things, as indicated previously, the Lesson Design and Implementation sub-scale was intended to identify recognition for student preconceptions and knowledge, exploration before formal presentation, and inclusion of student ideas in classroom direction. The other sub-scale (procedural knowledge) was also intended to identify physics lessons that used scientific reasoning and a variety of representations to characterize phenomena, make and test predictions, and engage students in thought-provoking activities and self-reflection and in intellectual dialogue. Data from the observed classroom lessons showed that formal instruction/presentation of the lessons occurred with little or no students' exploration.

The focus and direction of the lessons were primarily teacher directed. In the practical activities, for example, students did not have the opportunity to state what they thought was going to happen (predict) before data were collected. In addition, provisions of time for students to evaluate their thinking were virtually absent because very few ideas were elicited from the students. The lessons observed were, for most of the time, a knowledge transfer from the teacher to the students. Further descriptions and examples of Nick's teaching and post-lesson interview are presented in the following sections.

Conceptions about Teaching

The analysis of Nick's interview and classroom observation data indicated that he held two main conceptions about teaching. These were "telling the history of physics to make students see how things developed" and "providing learning opportunities for students to help themselves and

help others.” It was not clear where and how the first conception was developed. However Nick claimed that he developed the second conception at the time he was a teaching assistant at the university and that this was further consolidated during his teacher education course.

Telling the history of physics to make students see how things developed. According to Nick, the history of science, and physics in particular, had always been an interesting story for him. He mentioned that if he hadn’t been a physicist he probably would have been an historian. He asserted that the easiest way of understanding a concept was to consider the way it was first understood. Therefore, he believed that the discoverer of something probably had the most simple and basic way of understanding it, even if this understanding wasn’t quite correct, Nick believed that telling his students about this should be a starting point to launch into a more complicated explanation. This conception about teaching was demonstrated in some of the lessons observed as he told stories about personalities like Hans Christian Ørsted and Michael Faraday.

Providing learning opportunities for students to help themselves and help others. Nick also believed that the best way to enable learning in the classroom was to ask students to explain what they understood to somebody in their peer group. As a student and also a research assistant, he recalled a phrase often heard at the university that “you truly don’t understand something until you’ve taught it.” Nick was a strong believer of peer teaching, where the students are helping each other, and he wanted to see that happening in his classes.

To me the best indication of learning and the best learning that happens is actually when the students are helping themselves and helping others. I would very much like it if we had more time to do a lot more peer teaching work.

(Nick)

Even though Nick believed and advocated strongly for peer teaching, data from eight classroom observations of his lessons showed that he did not use this approach during these lessons. He explained during the interview that it was quite difficult to achieve collaborative student learning in the classroom due to time constraints.

There's not a lot of opportunity for inquiry and investigation. It's a time issue as much as anything because you have to give opportunity for them to learn themselves and then explain to somebody else, and you know, sometimes their explanations aren't good so you end up having to... (Nick)

He further indicated that, if for example, he wanted students to find out about how a capacitor works, that alone would take at least a week, whereas he could afford to spend only two days on how a capacitor works. Thus, he wasn't using the approach in teaching.

Classroom Practices – Teaching Approaches

This section reports on the teaching and learning practices and approaches that transpired in Nick's physics classroom. Generally, lessons in both classes (Year 12 and 13) started with the teacher (Nick) writing a question on the white board. Students would then be asked to solve the problem within a specified period, normally between five to ten minutes. In almost all the lessons observed, a question was used for revision of students' previous knowledge (content recently learned). The solution to such questions was most often presented on the white board by the teacher. This was followed by the teacher introducing the day's topic to the class and verbally outlining the activities to be undertaken. The activities most of the time included exercises from the workbook (and textbook), copying notes from PowerPoint slides, computer simulations, and writing and drawing tasks on the white board. Lessons normally ended with a brief recap of the day's activities and textbook homework for the students.

Data from eight observations of lessons about Electricity and Magnetism showed that there was a relationship between Nick's first conception about teaching (telling the history of physics to help students see how things developed) and his teaching practice. In other words, he often narrated the history of scientists/physicists to the students, aiming to stimulate their curiosity and encourage their participation. In one of the lessons on electromagnetism, Nick told the class the history of Hans Christian Ørsted, a Danish physicist and chemist who discovered that electric currents create magnetic fields, an important aspect of electromagnetism. This was followed by the history of the English scientist, Michael Faraday whose discoveries included electromagnetic induction. Summary information on these great personalities was often included in the PowerPoint notes for students. Similar stories were told about German physicist Gustav Kirchhoff and British engineer John Ambrose Fleming in separate lessons on Kirchhoff's circuit laws and the magnetic field around a current-carrying wire respectively.

On the other hand, none of the lessons observed gave a significant place to Nick's second conception about teaching – providing learning opportunities for students to help themselves and help others. It was revealed during the interview that a lack of time and the demands of the curriculum rendered this conception practically impossible to implement. Further details on this are presented in the next section. Most of the lessons observed did not involve practical work. Only a few of the lessons did involve practical activities where students had the opportunity to perform an experiment as part of the main lesson rather than a whole session being devoted to practical work.

There was not much variety in teaching methods. Lessons were predominantly characterized by two things. First, there was a standard note-taking section where students copied notes from PowerPoint slides. While the students were writing, Nick would be explaining the slides and sometimes providing further details and illustrations on the white board. The second characteristic

was working on exercises from textbooks or workbooks. This activity was almost an everyday occurrence and appeared to be the predominant teaching method. During the interview, Nick stated that, due to limited time, there were still elements of rote learning and chalk and talk in his teaching because there were some basic facts and things that students just needed to know. He further stated that, students had to memorize or learn some things to be able to go to the next step.

Sometimes, it is just a case of knowledge transfer for short... where they've just got to get this information, you know, you can't do as many of the good things as we might like to do. So there are still elements of rote learning and chalk and talk, but there are some times when that seems to me to be the appropriate method.

(Nick)

With regards to the problem solving exercises, students most of the time solved such physics problems individually. Sometimes, Nick would lead a discussion on the white board where the ideal solutions were presented. There was little encouragement for students to solve physics problems in groups. This was consistent with what Nick indicated on the questionnaire, that students most of the time worked on physics problems individually and sometimes worked in groups. While students were solving such questions from the workbooks, Nick, most of the time would be providing guidance and responding to students' questions as and when necessary (but most of the time the classroom was quiet since students wouldn't talk or ask questions). In the interview, Nick emphasized that the language of physics is mathematics and that mathematics is an essential tool for understanding physics. He indicated that because not all of the students were good at mathematics, he tried to demonstrate most of the problem solving on the white board and sometimes emphasized mathematical presentation of concepts with the aim of meeting individual needs in the class. The analysis of classroom observation data confirmed that solutions to most of

the problems were worked out on the white board after students had finished working on them. In one instance, a student was called to present the solution on the white board. When realising that most of the students did not fully understand something, Nick, provided further tuition and projected an animated PhET simulation circuit to demonstrate the principle. He consequently advised the class to visit the PhET website for additional simulations.

Though collaborative work was not often encouraged, during the few practical sessions when it was observed, students worked in groups of three and four. However, after collecting the data from their experiment, students would resume their seats and individually work on the report in their workbooks. Experiments were most often performed by following instructions from the teacher. The instructions were normally projected onto the screen or given verbally. In one practical activity, which was noteworthy, students predicted the results in their workbooks before performing the actual activity. Later, white board illustrations were used by the teacher to explain the results. In another practical session, students were called, in groups of five or seven, to a demonstration table. Here, Nick performed the experiment and then later explained the results to the whole class. In this case, Nick used a demonstration due to the nature of the task, the hazards involved and insufficient resources to allow groups of students to do the experiment themselves.

Factors Constraining the Quality Teaching of Physics and the Low Numbers

According to Nick, the major hindrance to the quality teaching and learning of physics is the conflict between the curriculum and assessment. He explained that although he didn't have to teach the content for all of the externally assessed NCEA achievement standards at Year 13 level (worth 16 credits), there was an expectation from most of the universities that this would be done. In addition, students had to do at least three credits worth of internally assessed work if they wanted to receive their NCEA certificate with an endorsement. Nick further explained that if students failed the internally assessed standard they would be ineligible for an endorsement, so he

had to do two internals. He therefore described the course program as “quite prescriptive”, providing little or no time to explore content beyond the curriculum.

There’s my course, 23 credits which is quite prescriptive. I have to teach Kirchhoff’s Laws, I have to teach internal resistance, I have to teach capacitors and inductors for DC, I have to teach capacitors and inductors for AC, I’ve got to do LCR circuits, I’ve got to do resonance. There’s my standard, very little room and time to explore wider than that in the curriculum. (Nick)

Nick also indicated that the content was difficult, and wasn’t something one could rush through.

I’ve tried to follow as many of the tools of good pedagogy as I possibly can. Sometimes the practicality and time limitations take over. I have so many periods to teach the course, you know, so if you spend a lot of time explaining things to get them to understand, there’s no time left over for a lot of extra exploration. (Nick)

In addition to his teaching workload, Nick was frustrated by the rate at which his administrative load was increasing. He felt that it occupied time that he would otherwise use to prepare interesting physics lessons. He explained:

The requirements for filling in forms even if they’re electronic, is more than it was even ten years ago and so we’re ending up not spending as much time preparing interesting lessons. We’re not spending as much time actually enjoying teaching in the classroom because we have so many other things on our plates. (Nick)

Another constraining factor mentioned by Nick was the nature and structure of junior science. Nick asserted that the curriculum alignment had watered down Year 11 content too much as far as physics was concerned. He was especially concerned about Year 11 mechanics, which no longer included vectors. According to him, that had created a huge gap between Level One (Year 11) and Level Two (Year 12) physics. He indicated that he now had to teach all of the vector mathematics at Level Two and for that reason he usually ran out of time teaching the Level Two course.

So when they come to Level Two they've never met a vector before so I have to teach at Level Two all the vector mathematics and the concepts and that's one of the reasons why the Level Two course is even worse than Year 13 for finishing. (Nick)

Again, he indicated that there were problems with the alignment of the curriculum and the achievement standards for NCEA. He considered the removal, of vectors from Level One to be a backwards step. In the interview he made reference to the initial draft of the realigned standards, in which mathematics had been completely taken out.

At one stage they were looking at taking all the mathematics out completely. It was going to become descriptive. We got a draft presented to us which had no mathematics in it. So it was completely descriptive and no calculations. We fought that one pretty hard, you can't do physics without mathematics. (Nick)

With regards to the low numbers of students involved in physics and the low numbers of physics graduates wanting to train as teachers, Nick admitted that the numbers had always been small and he couldn't foresee that situation changing. He attributed the problem mainly to the poor

public perception of teaching, the money involved in teaching compared to other professions, and the required teacher subject matter content knowledge. Nick felt that teaching was generally “perceived as being very hard” and “not an easy thing to do.” Added to this was the frequent negative media reporting about teaching.

...and you read of all the bad things about teaching, but you don’t read about all the good things. So the media doesn’t, well the media in general doesn’t help I suppose. (Nick)

Nick felt that most physics graduates would want to do research or prefer an alternative career where they could receive a greater financial reward than in teaching. He indicated that many of his own students had already decided to become engineers because they thought that this would offer them more money.

And you’re dealing with stroppy teenagers and the money’s not all that good compared to some of the other professions that you can do with a Bachelor’s degree or even better. They already have an idea, maybe they only want to be an engineer because they think there’s a lot of money in it. (Nick)

About subject matter content knowledge, Nick considered that it would be nice if all physics teachers had postgraduate degrees. In his view, the Bachelor’s degree is a good start but it doesn’t give one an in-depth content knowledge to teach the standard as expected, especially with scholarship students. He acknowledged that the content was difficult and that students undoubtedly found it difficult, hence teachers would need more subject matter content knowledge beyond the level covered during the Bachelor degree.

Ways for Improving Physics Teaching and the Numbers Involved

“Time, give us time”, was the first thing Nick suggested for improving the quality of physics teaching. As reported previously, the current teaching load, assessment practices and paper work seemed to have taken up the time that could have otherwise been used to prepare interesting lessons and to explore topics in greater depth. His second suggestion was to encourage as many postgraduate physicists into teaching. That is, to recruit more qualified physics teachers. He stressed that a lot of physics teachers either have no physics in their background or they have maybe a Stage One paper or a Stage Two paper and therefore have studied only a limited amount of physics. He emphasized that although these teachers could read ahead from the textbooks before they teach, they don’t have the depth of knowledge and the ability to solve and handle difficult situations in the physics classroom.

...so when they get a scholarship student, a student who’s genius level, it’s very hard to enthuse them, to challenge them. It’s very easy to teach the material, because you can look ahead in the textbook, but challenging them, they ask a question about quantum mechanics, or they ask a question about relativity. It’s not in the curriculum much, but you know, you need a depth and extent of knowledge to be able to answer those questions. (Nick)

He suggested that if such teachers were recruited, they would need more content preparation and that professional learning courses should be organised to help develop their skills and also improve upon their subject matter content knowledge. At the time of the study, Nick was involved in providing some sort of professional learning to colleagues who taught junior sciences who felt they needed more understanding in certain physics concepts so they could teach those concepts better.

To increase the numbers involved, he observed that, teaching in general needed to be positioned as a more attractive career. Part of it, as he had indicated earlier, was the financial reward and he mentioned that his actual take home pay had dropped, not in dollar terms but in real terms. He added that salary increases had been lower than inflation for at least the last six years, and so if he was looking at career choices again, he would think twice, about becoming a teacher. Regarding the training of physics teachers, he thought there was an obligation on the universities to continue to prepare physics teachers. He stated that those teaching university physics courses should understand that some of the people in front of them would make very good teachers and so students should not just be prepared for undertaking research.

The university lecturer in the department in front of a course of students, maybe thirty students in a course, needs to try and encourage some of those students to see that communicating physics is fun. It needs to be presented as a valuable thing to do with your time. (Nick)

Professional Learning Experiences

In terms of professional development, Nick indicated that there was a school-wide professional learning initiative focussing on pedagogy. With regards to physics, most of Nick's professional development in physics had been through personal reading, followed by NZIP conferences, listening to presenters and asking questions and learning from them. He explained that he used Facebook as a reader and had subscribed to New Scientist, Scientific American, and Physics Today. He added that the readings in particular had been useful because they helped him to focus on things that he was either interested in or that he could use to attract student interest. He described how effective this had been to him in the following statement.

So this year for example, while I was teaching Nuclear Physics, there was a paper in New Scientist about measuring the mass of a proton and the two different ways of measuring it gave two different values where the uncertainties didn't overlap. And I was teaching uncertainties to my Year 13 students at that time, and what we used them for. Why, if you want two numbers to agree, the uncertainties have to overlap. And so this was good timely professional development for me, to know this was what was going on and be able to use that with my students. To say well this is why we're learning how to do uncertainties, because without them, you're just guessing. (Nick)

Findings from Nick's Students' Focus Group Interview

There were a total of 47 senior physics students (twenty four Year 12 and twenty three Year 13) in Nick's class. Of this number, twelve (four Year 12 and eight Year 13) students consented to participate in the focus group interview. Two focus group interviews were therefore organised with the students. In responding to the question, "Do you enjoy physics lessons and what makes you enjoy physics lessons or not?" nine students indicated that they generally enjoyed physics lessons when they understood what was being taught, especially where they could relate the concepts to the real world. That is, they enjoyed some parts of the lesson, those that were easier to understand. Thus, the lessons were not enjoyable to them if they were not able to comprehend what was been presented.

The Year 12 students in particular found physics to be as an interesting and well-rounded subject and enjoyed it because it was a mixture of theory, mathematics and practical work. One student commented:

I like how we do practicals once in a while and it's not all writing. It's a bit of everything. I like how it's a mix of theory, mathematics and a bit of practical work as well. It's just a well-rounded subject. (Boy, Year 12)

The remaining three students in the focus group categorically stated that they did not enjoy physics lessons. They explained that, it was quite hard to understand because there were a lot of concepts to cover in such a short amount of time. Also, there was a lot of revision needed outside the classroom which made it quite difficult for them. Again, they believed that the lessons were pretty much focused on copying notes and the practicality aspect of the subject was missing, as exemplified by these comments.

I don't enjoy physics lessons because there's a lot of a concept to cover in such a little amount of time. I don't get the concepts and if I don't get it I just zone out and don't listen. I get bored. (Boy, Year 13)

To be honest no, I don't really enjoy physics class. I find it's a bit too serious and a bit too focused on copying notes off the board, more than actually doing it. (Boy, Year 12)

One particular student stated that he did not enjoy physics, however, he was doing it because he needed it for his qualification. When asked if they were happy with their performance, six students in the focus group were reasonably happy with their performance because they had gained an excellence in their practice (internal to the school) exams. However, they were not complacent and appreciated that they needed to learn more for the end of the year exams.

Yes, because I've got straight excellences which is the top mark, and in previous years I've had similar sort of stuff. (Boy, Year 13)

I got two excellences which I was aiming for so I was really happy with that.

For the external exams I wasn't quite as happy because I intended to put more work in but I didn't end up really having enough time to do it, but hopefully will be able to put enough work in for the end of the year. (Boy, Year 13)

The other six students mentioned that they were somewhat happy with their practice exam performance and indicated that they had not done enough study and that a bit more work would be required before they sat the end of the year exams.

Not exactly too happy with it. I don't enjoy it that much, or like studying outside class with it. So I haven't done too much or enough before the internals, so performances haven't been too good, I definitely need to more work for the end of the year. (Boy, Year 13)

When asked what made learning of physics difficult for them, almost all the students in the focus group referred to the mathematical equations and formulae, lots of concepts (overloaded content), symbolic notations and lack of time. The majority of students (ten students) observed that physics was difficult to learn because it relied heavily on mathematics. They mentioned that there were too many equations and formulae and these were difficult to learn and understand. Also, they observed that on the formula sheet, the equations had a lot of variables (symbolic notations) which have different meanings and this often confused them. Again, the students expressed that there were a lot of concepts taught and to be learnt in a short amount of time and this made learning physics difficult.

I find all the equations difficult to learn because there's so many and you get so little time in the exam too... yeah just so many equations, get confused because the same letters and muddled up a bit. (Boy, Year 12)

The concepts are just too many and difficult to understand and the equations that go with them. I find that it can be quite hard to apply the concepts properly to the written questions, and I often struggle on those sorts of questions. (Boy, Year 13)

The remaining two students in the focus group however, had something different to tell. One of them indicated that he was generally not good at memorisation and easily forgot almost everything that was learnt previously. According to him, this had impacted heavily on him because he did not get good results in almost all his subjects, not only physics. He expressed the view that physics was the hardest subject for him since by the end of the year, he had forgotten almost everything and had to re-learn it all.

I'm very bad at remembering stuff, I can usually understand everything that we're doing, but I've forgotten it by next lesson or next week and then by the end of the year I've forgotten everything so I've got to re-learn it all, that would undoubtedly be the hardest thing. (Boy, Year13)

Another student mentioned that essay writing and providing explanations to scenarios made physics difficult for him. He would like to have a definite answer, like a number for his answer and not have to include any explanations. He believed he wasn't strong at essay writing and explaining things and therefore ended up receiving low marks.

When asked how they would like their physics teacher to change his teaching style or changes that might make physics more interesting to learn, almost all the students articulated similar views. Although they admitted that the teacher was “pretty good,” they wanted to be given more responsibility in the class, have more hands-on-activities, more group activities and discussions and have more time for explanations. For instance, the students observed that, the class was virtually controlled by the teacher, since he always decided what was to be done. According to them, having more responsibility and time to work on areas that they thought needed development would help improve their learning and their grades.

I'd like him to be sort of less controlling but give us more responsibility sort of thing, like give us the responsibility to do the practical, give us the responsibility to like do our notes, and you know that gives us the responsibility of our results. (Boy, Year 13)

The students expressed the view that instead of having a general physics lesson which was supposed to cater for the whole class, they would prefer to work in smaller groups, do lots of questions and be given more time to discuss physics problems between and among themselves. In their view, they spent too much time copying the teacher's notes. They also indicated that the one-time explanations sometimes provided by the teacher on the white board were not enough.

Personally, I like discussion and doing lots of questions. I see some of the notes he teaches us are a bit irrelevant, like the stuff about the physics teachers and the people who made all the stuff, I don't, we don't use in exams so I don't really write that stuff down. (Boy, Year 13)

Another also stated:

What I really prefer would probably be a bit more time spent on doing problems and equations, and a bit less time doing the theory stuff, and not quite so in depth with the theory and history. We don't need the whole stuff that he taught us, it a makes it a lot harder to remember everything. Probably just less information, more dedicated to what we're actually learning for NCEA, what we need to learn for the externals. (Boy, Year 13)

A few of the students in the focus group indicated that changes to the teaching style wouldn't be that easy. They believed that the teacher couldn't really teach in any other way because there was so much to cover in such a short amount of time. They observed that unlike other subjects which finished new content knowledge at the end of term three, physics goes fully right to the end of term four because it is fully packed with so many concepts.

So you kind of have to stick with it, you've just got to do all the work with notes, there's no other way really, there's not a lot of time for explanations, not a lot of time for practicals, it's just notes and you've got to do it in your own time because it's such a big course and it's not like other subjects. (Boy, Year 13)

Why Students would or would not Become Physics Teachers

All twelve students in the focus group indicated that they would consider studying physics again at university because they would need physics for their chosen careers. The careers most of them aspired to were health science and engineering which would require some level of physics. Asked whether they would like to become physics teachers, the majority response was "not at all."

Most of them were not enjoying physics enough to make a career out of it. They also felt that there were a lot of other career opportunities that they would enjoy more than teaching. It appeared that teaching in general wasn't a career option considered by the students.

I feel that there's a lot of other career opportunities that I would much rather enjoy, and also I wouldn't really enjoy teaching generally, it's just not what I would enjoy. (Boy, Year 12)

I just don't think there's enough enjoyment in it for me to make a career, a job out of it. (Boy, Year 13)

Two of the students in the focus group pointed out that they might consider becoming physics teachers but that would be something later on and at the moment it was not a priority. They would want to concentrate on their dream careers first more than anything else. Their views are presented below.

I would consider being a physics teacher although it's not something that I truly want to do, maybe something to do later on. But right now I wouldn't really think of it as something that I truly want to do. (Boy, Year 12)

I'd definitely consider it, but my main priority is engineering, but I have in the past thought of it. (Boy Year 13)

One other student in the group would consider being a teacher but was not sure if he would be a physics teacher. He suggested that he would prefer biology to physics because he enjoyed biology lessons more than physics.

I don't enjoy physics but, maybe teaching another subject may be a career for me if.... another option, maybe biology or something because I enjoy that, but not Physics. I wouldn't be passionate enough about it to teach Physics. (Boy, Year 13)

The Case of Vicky

Education Background and Experience

Vicky was a physics teacher at School C, an integrated Catholic girls' school. She was aged between 31 – 40 years at the time of the study and had been teaching for ten years. Vicky was the only physics teacher at School C and employed on a part-time basis. She was teaching a total of 12 periods per week and taking one Year 13 class and two Year 12 classes. She was also the Assistant Head of Science. Vicky had an honours degree in physics, and had previously worked for the Police for a year before training as a teacher.

Asked why she stopped working for the Police and deciding to train to become a teacher, Vicky responded that she had always loved learning and always loved teaching. When she was in high school, a lot of her friends would go to her house because she had (as her friends told her), a way that she could explain things that made sense to them. Vicky had enjoyed teaching her friends in that study group and loved being part of it. As part of her work for the Police, Vicky taught at the Police College at Porirua, which sparked her interest again in going into the classroom. At that point, Vicky decided to resign from the Police, return to Christchurch and undertake teacher training.

At the Police College, I sort of looked at myself in the mirror and said, what are you doing? You know what you're meant to be doing. So after a year at the Police, which was very interesting, but not where my heart was, I resigned, came back to Christchurch and did teacher training... and then there was no question that I was going to be a physics teacher, because by that stage I was passionate about my subject. (Vicky)

Vicky's passion for physics was internally motivated rather than having been inspired externally by another teacher. According to her, she had a terrible physics teacher at school and her high school experience was an unhappy one. She wanted to drop physics as soon as she could, however, at university, she realised that she was good at mathematics and this had helped her to understand most of the physics concepts. During her teacher education Vicky particularly enjoyed her practicum experiences. She explained that the philosophy of the ITE provider was to focus more on classroom management and less on theory. They used to spend more time in the classroom practicing their profession which she whole-heartedly enjoyed and was quite pleased with.

...and so the philosophy was that you had to be in classrooms as much as possible, thus, we had four sections (professional placements), each seven weeks long, so at the end of your year-long course you'd spent twenty eight weeks in a classroom teaching..., they openly said, you are not going to write a single essay. Because you're not going to ever write an essay as a teacher, your job is to present information. So when you want to be assessed, you present the information verbally, because that's what you have to do in a classroom, hence you might as well practice. And I really, really enjoyed that.

(Vicky)

Vicky added that she thought most beginning teachers find their first year challenging because they are not used to the intensity of teaching for extended periods of time. She asserted that her teacher training prepared her (and her colleagues) well for the classroom and that she was comfortable and confident during her first year of teaching due to the exposure she had working with classes.

Using the Observation Checklist

I observed Vicky teaching physics nine times with her senior classes – five at Year 12 and four at Year 13. Vicky's teaching was rated using the RTOP checklist. Both Vicky and I completed the observation checklist for each lesson. Both scores were matched up and any differences were reconciled. Table 26 shows the average scores on the RTOP constructs for Vicky and this indicates how her teaching was rated. She was interviewed at the end of the observations.

Table 26: Vicky's Average Scores on the RTOP Sub-Scales

RTOP sub-scale	Average score (out of 20)
Lesson Design and Implementation	12.1
Propositional Knowledge	15.1
Procedural Knowledge	10.3
Communicative Interactions	11.4
Student/Teacher Relationships	15.3
% Total	64.2

As seen in Table 26, Vicky had an average total score of 64.2%. Since this value is greater than 50, her teaching indicated considerable presence of good pedagogical practice. Two sub-scales, student-teacher relationships and propositional knowledge, recorded high scores of 15.3 and 15.1 (out of 20) respectively. Student-teacher relationships for example, looked at lesson interactions, whether students actively participated in the lesson – both minds-on and hands-on, whether students primarily took responsibility for their own learning, whether the teacher was a patient listener and acted as a resource person. Data from nine observed lessons on Electricity and Magnetism showed that active participation of students was highly encouraged. Students were also encouraged to generate alternative solution strategies and way of interpreting

results/evidence. In most of the lessons observed, Vicky tried as much as possible to act as a facilitator, working to support and enhance students' understanding of the concepts she was teaching. She did this through brainstorming, listening to students and group work.

Even though Vicky encouraged active participation and students sometimes worked in groups where they communicated with one another, Vicky wanted to lecture most of the time and give detailed explanations and/or information about the concepts being taught. Most of the lessons were not characterised by the use of student discourse. That is, students had little opportunity to communicate their ideas and contribute to the lesson. This somewhat explains the low average scores of 10.3 and 11.4 for procedural knowledge and communicative interactions during Vicky's classes.

Conceptions about Teaching

The analysis of the classroom observation data and Vicky's interview indicated that she held three dominant conceptions about teaching: "students learn by doing", "having an atmosphere of togetherness" and "feeding students with content knowledge and detailed explanation." It was noticed, during the interview, that the first two conceptions had developed through her teaching qualification whereas the third one had developed while teaching at her current school.

Students learn by doing. One common theme which ran through Vicky's interview was that she cherished hands-on activities and would like her students to do more hands-on activities in order to discover scientific knowledge for themselves. She indicated many times that she would "like students to understand physics through doing experiments." As mentioned previously, she gained an understanding of what teaching was when she herself was put in the classroom to practice. Learning by doing was the main philosophy of her teacher education programme and Vicky had carried this along with her. Vicky was also asserted that, collaborative learning and

peer instruction were useful approaches to enhance students' learning. However, due to the demands of assessment and other time constraints, the conception that 'students learn by doing' had slowly been pushed out and replaced by 'feeding students with content knowledge.'

You learn by doing is a major philosophy to me but I do this infrequently due to the pressure of the assessment and time constraints. (Vicky)

Having an atmosphere of togetherness. According to Vicky, effective teaching and learning happens when there is an atmosphere of togetherness. To her, effective learning starts with creating the right atmosphere, which needs to be positive. She reported the bad experience with her own physics teacher at high school, which almost made her opt out of physics. Consequently, she determined not to subject her students to a similar experience.

My physics teacher didn't try to connect with us in any way, there wasn't any sort of a nice atmosphere when you walked into the room. You walked into the room and the purpose was, he would be talking at you. There was no interaction, he just could not connect with us. I just really felt that there was no connection between the teacher and me. That, I mean I can sort of, it's hard for me to put myself back into my fifteen year old self, it just felt totally irrelevant in my life. I didn't do very well in physics because of him. I think I was, because I was always good at mathematics, that basically helped me pass. (Vicky).

Vicky was convinced that in order to help the students to understand what they are taught, a good rapport between the teacher and the students must be established. Based on this conviction, she

wanted to be accessible to the students so that they could feel free to ask her any questions whenever they did not understand, as illustrated by her following statement.

...and setting up the environment that allows the kids to feel that if they don't get it they'll tell me, and in that way, having that close relationship. I know if things aren't working, because I can see it, and they're brave enough to tell me. Because it's okay to say in my classroom, I don't get it, let's try it again.
Can you explain that in a different way? I still don't get it. (Vicky)

Vicky indicated that this important aspect of teaching and learning (atmosphere of togetherness) was missing during her own high school days, a situation she described as a "horrendous experience." The atmosphere of togetherness was demonstrated during the observations. Vicky and the students were all in the classroom to learn. It was considered okay to ask questions and to occasionally get off topic, and it was okay for students to ask Vicky questions about what they saw on television the previous day.

Feeding students with content knowledge and detailed explanation. It was Vicky's wish to have her students perform experiments to discover knowledge. She also desired to be more innovative to make physics more appealing to students. These long held aspirations were challenged by what she termed "demands of the assessment and credit points", especially, in her present school. She bemoaned the fact that the school and the students seemed more concerned about accumulating credits to gain university admission than understanding physics. Hence rote learning was what the students preferred because that would assist them to pass the end of year examinations.

They (students) expect me to tell them directly what they are supposed to know in order to pass the Year 12 and Year 13 exams. Because they're so used to learning to pass the standard. (Vicky)

Vicky's present school had a goal of students achieving a high percentage of university admissions and scholarships, hence, every teacher was expected to help students perform well in the end of year examinations. Instructional activities that were perceived as unnecessary for promoting the goal of the school were met with mixed reactions and in most cases considered undesirable. She was unhappy about what was happening, as she described in the following statement.

...if you want to be a bit more innovative, it is terrifying...the battles I have to fight, to do this. And the fights I have to fight with my Head of Faculty, because her focus is getting the kids to pass the exams. The rote learning things, because that's what it says in the end of year exam. I'm horrified. And now I'm having these big fights with senior leadership. (Vicky)

The present school context was creating a challenge for Vicky and the conception of teaching by feeding students with content knowledge and detailed explanation was at variance with what she believed in.

Classroom Practices – Teaching Approaches

This section examines how the conceptions about teaching held by Vicky were reflected in her teaching practice. Each lesson observed tended to reflect on different sets of minds on approaches to teaching and learning. Lessons most of the time began with the teacher outlining the activities/objectives to be undertaken and recording this on the white board. She would then review students' previous knowledge, sometimes through oral questions and answers, and at times,

students listened to her as she went through the previous lesson using PowerPoint slides. After the preview of the previous lesson content, she would introduce the lesson, and write the topic on the white board. Vicky would take students through the activities outlined on the board. Almost all the lessons observed were PowerPoint presentations accompanied with white board illustrations. . About half of the lessons observed involved practical work, where students had between 10 to 15 minutes and a maximum of 20 minutes to engage in hands-on activities. There was no organised practicals lasting for the entire lesson. Lessons usually ended with a summary of the day's events and homework being set for the students.

Data from nine classroom observations with Vicky teaching physics showed that there was a relationship between what she believed and her teaching practice. She tried as many times as possible to have students perform some type of experiment and she encouraged them to participate in this. Students worked in groups of three or four on almost all the practical activities. What was significant for this class was that students sometimes had the opportunity to plan and carry out their own designs for experiments. When students undertook such experiments, Vicky was seen moving from one group to another, interacting with the groups and asking members in the group "why" questions to stimulate their thinking. She wasn't just interested in questions and answers but rather encouraged students to reflect upon the issues under investigation and would always ask students for expansions of their reasoning. Often, different responses from students to the same question were considered and compared.

As part of her quest to make physics more appealing to the students, interactive demonstrations were sometimes used in the normal lecture-type lessons. In one such lesson, Vicky was describing a generator to one of the Year 12 classes. Using PowerPoint, she displayed a generator animation on the white board. After a while, she stopped and encouraged the students to draw all the forces involved. The students particularly enjoyed this. She used this strategy often,

frequently employing PhET simulations. Sometimes, she referred students to PhET simulation links and asked them to work on these as homework. Though she had to teach what was going to be assessed, relevance was absolutely important to her. She felt that it was her role to make physics relevant to the students. To do this, Vicky tried to show how what they learnt linked to the real world and emphasized where physics knowledge was important. She showed students several National Aeronautics and Space Administration (NASA) videos and during these times physics concepts were consequently pointed out and explained to students.

Like most of her colleagues, Vicky was resolute “not to teach in the same way as she was taught in high school,” and was determined to teach beyond what was going to be assessed. She had a scheme of work, which according to her, was entirely different from her colleague physics teachers. In the scheme, mechanics, waves, electricity and magnetism, and nuclear physics were not taught in one block. They were “chopped” into pieces and were taught in an integrated manner. Added to the scheme were “things that were not part of the achievement standards.” Vicky mentioned during the interview that context based teaching was important to her and this was visible in most of the observed lessons. In one of the electricity lessons with her Year 12 class, which she had entitled “Producing Electricity in New Zealand”, electromagnetism was taught alongside aspects of nuclear physics. There were arrangements made to visit the University of Canterbury to allow the students to learn more about nuclear physics and how solar and nuclear energy could be used to produce electricity in New Zealand. During the interview, Vicky explained the problem she was facing with this teaching approach.

I make it a context based thing but at the beginnning of the year it is a real struggle for the kids to even understand what I’m doing. Because they’re not used to this and they don’t see physics as a whole. (Vicky)

Vicky used lots of PowerPoint presentations and videos in her teaching. Students were often impressed with the content of the videos and would ask questions, most often “why” questions. In all cases, Vicky did her best to provide answers to the satisfaction of the students. When such videos were played, further descriptions and explanations with diagrams would be provided by her on the white board, after which students would be asked to copy notes into their books. Note taking was quite common and most of the notes were projected for students to copy. In addition, white board illustrations were also prevalent, usually relating to calculations, drawings and graphs.

Students’ exploration and prediction were sometimes used in the lesson presentations. In addition to the practical sessions where students had some opportunity to carry out investigations of their own design, students sometimes had the opportunity to contribute to the main lesson through the predict-observe-explain strategy. One of these situations occurred when Vicky was teaching a lesson on magnetic and electric fields. After demonstrating on the white board how magnetic field lines are drawn, she gave out sheets of papers to students and asked them to predict and draw the field lines produced by two bar magnets for three different arrangements of the magnet poles. Later, a practical demonstration was carried out on the predictions after which white board illustrations were used to explain the results to the class. A similar predict-observe-explain approach was used when she was teaching a lesson on the magnetic field around a current-carrying wire.

Nonetheless, for most of the time it was Vicky who presented students with content related concepts. Also, Vicky reviewed most of the numerical physics problem-solving activities on the white board. Only occasionally did she invite students to demonstrate problem-solving methods. As previously mentioned, Vicky spoke about this during the interview and explained: “this is what the kids are used to because they are learning to pass the standard.”

It is worth mentioning that Vicky was positively influenced by the reflections she completed for the observed lessons. She was enthused about the awareness of her teaching practices, especially what she thought she ought to do but wasn't doing. She tried to engage students as members of a learning community by promoting active participation and negotiation of ideas. This happened most frequently during the practical parts of the lesson

Factors Constraining the Quality Teaching of Physics and the Low Numbers

"I think the biggest difficulty, the biggest roadblock by far, is assessment" This was Vicky's immediate response with regard to factors constraining the quality teaching and learning of physics. She mentioned that the situation was not only impacting on her as a teacher, but impacting on the students in their attitude to learning because for the students, it is not about learning but rather the accumulation of credits. Vicky described the situation as "unfortunate" because to her, it seemed that the NCEA was not aligned to the curriculum in any way. She picked up the 2007 New Zealand Curriculum (NZC) document, and read:

The curriculum gives schools the scope, flexibility and authority they need to design and shape their curriculum so that learning and teaching is meaningful and beneficial to...in turn the design of school's curriculum should allow the teachers the scope to make interpretations in response to the particular needs, interest and talent of individuals and groups of students in their class. (read from curriculum document)

She explained that the curriculum aspires to make learning relevant to learners which she loved and wanted to do. She liked the new curriculum and believed that it was on the right track. But while students had to be assessed by NCEA examinations, she believed that teachers were not

going to be able to implement it. To her, the aspirations of NZC seemed to take second place to satisfying the demands of the assessment system.

I am being forced to teach what NCEA wanted us to assess...at the end of the day, I am being judged by how well they (students) do in tests, and they are getting judged by how well they do in the test. (Vicky)

She also indicated that NCEA has become harder and harder, which meant she had to take more and more time preparing students for these assessments. She thought that this took them away from learning, because in her opinion, preparing for assessments is different from learning.

Vicky expressed concern about some of the achievement standards being taught in schools. She particularly mentioned “Modern Physics” and said that this standard included physics content that was current around 1910 at the very latest. According to her, New Zealand has adopted what the Americans were doing during the early years of the space programme. She observed that the physics that they learnt then was basically important for the space race and indicated that physics concepts such as optics, satellite technology, orbits and gravitation were really important then, but that kind of physics, is “totally irrelevant now.” She struggled for words to describe why the NCEA system required her to teach this content rather than about semiconductors, transistors diodes and thermodynamics.

I cannot believe that I am surrounded right now by things that have semiconductors in them, and yet these kids leave high school, haven't got a single clue what a semiconductor is, how a transistor works, or even an NP junction, a diode. (Vicky)

Apparently, Vicky was very excited when the new curriculum was introduced and it was announced that the achievement standards would be aligned to the new curriculum. She was particularly enthused when it was advertised that NZQA was putting together panels to look at the alignment and she was keen to be on the physics panel. She stated: “I think I’ve got some big ideas of where we can take physics education to make it 21st Century physics education.” However, she was disappointed that there was no application process and people were picked and appointed to the panel. She was shocked by the outcome of the review, as she explained:

And what we got was just what we had before. We were told it was anonymous but I know some people who were on it, they were people who wrote the textbook. Now call me cynical, but if I have a textbook, don’t I have a financial stake in not changing anything. And so when the new standards came out, it was just totally, totally....I was just so disappointed.

(Vicky)

She further lamented the fact that the NCEA system required every single one of her tests to be checked by another teacher outside of the school. She intended to pick up this issue with the Assistant Principal responsible for curriculum and ask the Assistant Principal to stop talking to her (Vicky) about assessment but rather talk about curriculum. According to her, the *NZC* clearly states that (she again opened the curriculum document and read): “the purpose of assessment is to help teachers teach, and to help students learn...not all aspects of the curriculum need to be formally assessed.” Vicky then asked the following rhetorical questions: “Has anyone read this? Is anyone aware that this is what we are meant to be doing”?

The second constraining factor mentioned by Vicky was a lack of innovation by physics teachers. She explained that, from what she had seen at other schools and through the exchange

of timetables and year planners with colleagues, the entire school year seemed to be planned around completing achievement standards. She was not surprised though, and could understand why they (teachers) do that, as she explained in the following statement.

I can understand why, it is easy. It is easy to teach by Achievement Standards because this curriculum document gives you lots of flexibility but it doesn't teach, it doesn't tell you what to teach, while the standards do. So if you are a new beginning teacher or you're an established teacher who just wants to keep going, what they've always done, that's a perfect fit. (Vicky)

On the numbers of students involved in physics studies, Vicky observed that, the number of students who do physics because they like the subject is in most schools very small. She attributed this problem to the quality of physics teaching by general science teachers, who she said, are generally biologists and chemists that really don't like and don't really understand physics. She added that this was happening because of a lack of expertise to teach Junior Science and Year 11 classes.

We don't have the throughput, because not many physics teachers are out there...which means not many of us are teaching Junior and Year 11 classes. They don't see our passion for the subject, they don't get it taught very well. (Vicky)

Vicky also suggested that the content of the subject (physics) was another cause for the low numbers and low interest level. She believed that the achievement standards being taught and assessed in schools were uninteresting and irrelevant to the students. Although she had been trying

hard to make it relevant, she would prefer to teach semi-conductor physics which she believed would be more relevant.

In terms of the numbers going to the university to pursue physics and returning to the classroom, Vicky opined that there was little difference in how physics is taught at both high school and university. She asserted that conceptual understanding is not encouraged at university and therefore, students do not get to experience the beauty of the subject. As a result, physics becomes a more difficult subject which deters many students and hence they opt out at the early stages of the course.

I don't think physics is particularly well taught at university... conceptual understanding is not encouraged. Certainly, when I was there, and what I hear from students that are going there now, conceptual understanding of physics is not encouraged. (Vicky)

Furthermore, Vicky believed that the public perception of teaching is generally negative and that the teaching profession is under-valued. "If you wanted a job where you want to be valued, acknowledged and respected, then it would certainly not be teaching." She was particularly critical of the negative portrayal of teachers and teaching by the media, giving as examples reports that "teachers are lazy" and "male teachers are sexually harassing". She added that "very, very rarely to you hear from the media about the good things that teachers do". She therefore wondered if a graduate with a physics degree would want to choose a profession that values him/her so little.

Ways for Improving Physics Teaching and the Numbers Involved

To improve the teaching and learning of physics and increase the numbers of students taking the subject, Vicky suggested that the high stakes assessments in Year's 11 to 13 should be avoided so that teachers could spend more time teaching and helping students to learn. She also

admonished her teaching colleagues, suggesting that they should be more innovative by making context the focus of their teaching and think less about assessment. She believed that this would be really hard to do, because most teachers value the security of their employment and would not want to fight the battles she has fought so far. In order to attract more physics graduates into the teaching profession Vicky suggested that, due to the current high workloads of teachers, a better remuneration package should be put in place to reward good teachers.

Vicky acknowledged the shortage of qualified physics teachers and called for alternative ways of providing training. She believed that, as both short and long term measures, biology and chemistry teachers who have been teaching junior science should be offered instruction in physics so that physics teaching could be improved at junior level. To show how this could operate, at the beginning of the 2014 school year Vicky organised in-service professional development for the Year 11 science teachers in her school. Before they started teaching mechanics, Vicky had them complete the first seven questions of David Sokoloff's "Force And Motion Conceptual Evaluation" test. As Vicky reported, "they got them all wrong" and she used this as a springboard to organise instruction for the teachers. She explained that the teachers were eager to learn so they could improve their teaching of the subject.

...and to their credit, they were willing, and some of them were actually horrified to think that they had taught it wrong for years....and actually one of them came to me and said, this year I've enjoyed teaching physics so much more because I actually understand now.

Vicky created a "Hall of Physics" in her classroom. This collection of photos of famous physicists displayed on one of the concrete beams in the classroom featured short stories about the scientists. When asked about this during the interview she explained that physics is shaped by real

people, people who had lived just like us and she liked telling her students stories about them. One thing she was particularly passionate about was to create an awareness in the girls that she was teaching that the scientists were not geniuses but normal people who had a passion for physics. In one of the lessons she mentioned to the students that “though these people are old in the photographs, when they did their work, they were young.” She made particular reference to Einstein and $E=mc^2$ and said “Einstein was in his early twenties when he came up with many of his famous ideas.” Vicky wanted the girls to know this so as to erase the perception that only “certain types of people can pursue physics studies” and to encourage girls to see themselves as scientists. She referred to herself as a role model for the girls.

Professional Learning Experiences

As far as professional experiences are concerned, Vicky, expressed concern about the lack of physics professional development for teachers. The only kind of professional learning she could refer to were the cluster meetings organised by UC Education Plus. She described the cluster meetings as “really good”. She stated that the cluster meetings were collaborative in nature, where teachers meet to show each other things that work well and facilitate teaching and learning. Though she had attended a couple of professional development workshops run by NZQA, she indicated that these supposed professional development workshops were all about assessment and there was nothing on teaching and learning.

Vicky has been engaging in teaching as inquiry (Timperley, 2011), using reflection of her teaching practices in the classroom. She has been trying to understand her teaching practices and improve her content knowledge by giving herself challenging questions and scenarios where she tries to reflect on minds on approaches to teaching and learning to find solutions. She also reads a lot to update herself on current issues. In addition, she has been learning from the in-service

instruction she has been organising for the junior science teachers. One difficulty she faced was being the only physics teacher in her current school, which made it hard to associate regularly with other physics teachers. This was not a problem in her previous school where the science department was much larger.

Findings from Vicky's Students' Focus Group Interview

Eight students (out of 21) in Vicky's class consented to participate in the focus group interview. There were six Year 12 students and two Year 13 students. Thus, two focus group interviews were organised. Students in Vicky's class saw physics as having a strong relationship to their everyday lives and so they enjoyed most of the physics lessons. Almost all of the students stated that they enjoyed physics lessons when the content related to things that they could actually see and/or could make meaning out of it. Some of the topics that came up during the focus group interviews which students seemed to like were mechanics (torque, momentum) and nuclear physics. Although they described the teaching as good, most of them indicated that, physics could sometimes be repetitive and boring, especially the mathematics content.

I do enjoy most of the things, like, when it relates to things that we can actually see or that, like you're walking around and you kind of remember something from a physics lesson or see something on TV, that's probably how I find the Maths really boring because it doesn't really relate a whole lot, whereas the actual things like, torque and momentum and all that kind of stuff relates to every day scenarios. (Girl, Year 13)

I enjoy it sometimes, but it depends on what kind of work we're doing, in that specific lesson. It's good when it relates back to the world and how we can

benefit from it, or how we can use it, or how, like jobs use it and things like that, I think that's really interesting. (Girl, Year 12)

Although the students enjoyed most of the physics lessons, they seemed not to enjoy studying the subject. They described physics as “more demanding” and requiring a lot of time to understand most of the concepts, especially Electricity and Magnetism.

I don't like studying electricity, because I find it really hard to wrap my head around, just so much to learn in one topic. But I like studying mechanics. (Girl, Year 12)

I'm not a huge fan of studying physics but I think I prefer studying for one particular thing because just recently we were studying for both mechanics and electricity and it seemed like way too much to handle. When you're just focusing on one aspect of it, I find that quite interesting. (Girl, Year 12)

The Year 12 students especially, were unhappy with their overall performance in physics and wondered whether they would be able to make it through the standards. These girls were quite pleased with the internal but not the external assessments. They admitted, however, that it was their own fault because they didn't put as much effort into studying the topics as they did for their other subjects. One student stated:

I'm only happy with my internals, but I know I can do better in the externals because I think I don't really attach as much importance to it as I should've... I'm not really happy with the externals but I know that was my own fault because I didn't really try for them. (Girl Year 12)

The Year 13 students, on the other hand, were relatively happy with their performance but admitted that they could do much better if basic mistakes were avoided. They were happy with their practice exam papers and indicated how helpful these had been as preparation for the final assessments.

Just a bit disappointed, basic mistakes. But at least I know what I need to aim for at the end of the year, which is helping a lot going through the practice exam papers. (Girl, Year13)

Regarding the difficulty of the subject, different forms of symbolic representation, the abstract nature of physics, the over loaded curriculum and the numerous equations and formulae used were all mentioned by the students as contributing factors. About half of the girls indicated that the numerous mathematical symbols used make physics difficult to learn. They thought that the number of symbols was too many to remember and that these could be very confusing. One student could not understand why in magnetism the letter B is used to denote magnetic field. She indicated how confusing and frustrating it was that the same symbols occurred in different contexts (for example A for area and A for amplitude; W for work and W for watt; V for volume, voltage and velocity). The students appeared to have little understanding of the meanings carried by the symbols. They also saw the abstract nature of physics as problematic and wondered why they had to “imagine and assume” that certain things and conditions exist without actually seeing them. One student stated:

In physics we have to think about those things we can't see. Like the magnetic fields and current, and you get confused when you actually have to think and imagine about things you don't actually see. (Girl, Year 13)

Another commented:

I think it's just a whole kind of level of thinking that we've never really done before, which is kind of like a really big step up from Year 11... and that's kind of really hard to cope with. (Girl, Year 12)

Again, the girls observed that, it was difficult learning the content for the standards because there were many concepts to understand for each achievement standard. They complained of being pushed through lots of content with little time to gain a full understanding of the basic principles. Furthermore, the girls stated that they were not good at memorizing all the equations and formulae and that at times quite complex formulae had to be used to solve a problem. They lamented that it was challenging and demanding to commit the various mathematical expressions to memory, especially where the same symbols were used in different contexts. It appeared that finding the correct equation or formula to apply and performing the algebraic operations were difficult for many of the girls.

In response to the question on how they would like their physics teacher to change her teaching style or changes that might make physics more interesting to learn, almost all the students responded that they would like the teacher to continue relating physics to the real world. Also, the students wanted to have a balance between theory and practical lessons and wondered if they could have more hands-on activities. They described it as “tiresome and boring” sitting in class after class listening to the teacher and copying notes from the white board. In addition, they expressed concern about not receiving good instruction in physics during their Level One Science course. What they perceived as poor teaching of physics at Level One contributed to many of their student friends deciding to discontinue studying physics.

Getting a deeper knowledge of it when you're in your younger years, like having a bigger sort of focus on it in Level One Science, because they don't like really do that much and talk about it. What we do in Level Two is more interesting than what we do in Level One. (Girl, Year 12)

They didn't make it fun in Level One so a lot of people thought, oh I don't want to go on.... I didn't understand physics at all in Level One, it just confused me. Then I got to Level Two and it was quite a big jump but then once I got my head round it, like I found Level Three quite easy, compared to Level Two. (Girl, Year 13)

The girls seemed aware of the general shortage of physics teachers and that their school may be using non-specialist teachers to teach the subject at Level One (Year 11):

I have no idea of any physics knowledge from the previous level because we didn't have proper physics teachers to be able to explain it well...it's really hard if you're not a physics teacher to do it. (Girl, Year12)

Why Students would or would not Become Physics Teachers

When asked the question, "Would you consider studying physics again at university and why?" only three, out of the eight students who participated in the focus group interview, responded in the affirmative. Of these three students, two indicated they would only take physics because they needed it to gain qualifications for future careers. The other student stated that she found physics interesting and because she was good at mathematics and physics she would consider pursuing physics at tertiary level.

I just find it interesting, I quite like how as you get further along it just seems to interrelate with Maths more which is my strong point, so I will study physics at the university. (Girl, Year 13)

This was the only student who expressed a desire to become a physics teacher. She explained:

I mean, I really really like physics, if I understood it and I started to get much better at it, I guess why not, I can also teach it. (Girl, Year 13)

The remaining five students in the focus group would not consider taking physics again at university and did not want to become physics teachers. Three of them felt that physics was too difficult to cope with and did not want to study physics again. One student commented:

If I could be a physics teacher I would be so happy but obviously I can't be a physics teacher. I don't think I'd feel confident enough teaching students about a subject that is already hard. (Girl, Year 12)

Another girl stated:

I probably won't head towards that path, I'm doing it at Level Three, but I don't really want to travel down the physics path. I feel like I understand chemistry and biology better, whereas physics, I just feel so lost. At times, just compared to my other subjects I just feel like it's just too much for me. (Girl, Year 13)

The other two students in this group who would neither consider taking physics again at the university nor become physics teachers explained that they simply do not want to be teachers and that this had nothing to do with physics. They only wanted to have the knowledge but nothing more. It was clear from their comments that becoming a physics teacher, wasn't a career aspiration.

The Case of Bernard

Education Background and Experience

Bernard was a physics teacher in School D. School D was purposefully selected as an additional and alternative case study of a teacher who had switched disciplines. The physics teacher, Bernard, was a biologist who taught biology for almost ten years but then switched to physics and he had been teaching physics for the last 25 years. He was aged 50+ years and has had over 30 years of teaching experience. Bernard was both Head of Science and Head of Physics and his teaching load was 16 hours per week. He holds a Bachelor of Science degree in Biology and had also completed a Masters in Science majoring in Marine Biology. He then went to a College of Education where he obtained his Graduate Diploma in Teaching and Learning qualification. Bernard became a teacher due to personal interest. He explained that although his family were not teachers, he had always wanted to become a teacher even when he was 10 years old.

My father was a research scientist in actual fact, and so we haven't got many teachers there but for some reason teaching appealed to me. Since an early age and since I was ten years old I wanted to teach eight year olds and when I was twelve I wanted to teach ten year olds, I always wanted to teach a couple of years behind. So I ended up becoming a science teacher because I was interested in that. (Bernard)

As mentioned previously, Bernard was trained as a biologist but he was now teaching physics. Asked why he switched to physics, Bernard indicated that it was initially to cover a shortage in the school's staffing at his previous school at Rotorua. He enjoyed teaching physics and so had

continued to do this. When he came to his present school it was to take up a position as a physics teacher, as he explained in the following statement.

I think it was one of those funny stories. There was a shortage in our school of physics teachers, and they were looking around for somebody who was prepared to take the class, and so I taught Year 12 Physics in Rotorua for three or four years and quite enjoyed it. When I came down to Christchurch there was a position for a physics teacher, but not biology, which I took with all the challenges that implies as well. (Bernard)

Bernard did Stage One Chemistry, Physics, Biology and Mathematics at University. At the College of Education, he studied biology as well as general science and physics and his intention was to become a biology teacher. He indicated that he did about fifteen weeks of the course out in schools teaching and he enjoyed being in the classroom, especially with an associate teacher (mentor).

I think for me the most valuable exercise was teaching practice, going out and being associated with an associate teacher. The ability to go into schools to prepare me to become a teacher was probably the most valuable for me. (Bernard)

Using the Observation Checklist

As for the other teachers, the RTOP checklist was used to rate Bernard's teaching. Both Bernard and I completed the observation checklist after each lesson and the scores for each lesson were discussed to reconcile any differences. As mentioned earlier, some scheduled observations with Bernard were missed due to school activities, including students' internal assessment

activities, teacher professional development workshops and teacher-only day events. Thus, I conducted six observations with Bernard. The average scores for the six classroom observation lessons are summarised in Table 27.

Table 27: Bernard's Average Scores on the RTOP Sub-Scales

RTOP sub-scale	Average score (out of 20)
Lesson Design and Implementation	11.3
Propositional Knowledge	16.2
Procedural Knowledge	11.3
Communicative Interactions	12.0
Student/Teacher Relationships	14.7
% Total	65.5

Table 27 shows an average total score of 65.5% was obtained by Bernard. Since this score is greater than 50, it can be inferred that there was a considerable presence of good pedagogical practice. Among the five sections, a relatively high score of 16.2 and 14.7 were recorded for Propositional (content) Knowledge and Student/Teacher Relationships respectively. This gives an indication that the teacher (in this case Bernard) demonstrated a solid grasp of subject matter content knowledge and better approaches to teaching and learning that promoted understanding across topics and situations.

In addition, he presented lessons where students, both minds-on and hands-on, participated and took responsibility of their own learning. A lower score of 11.3 (out of 20) was recorded for Lesson Design and Implementation and for Procedural Knowledge, and these scores were similar

to the other three teachers. Further descriptions and examples of Bernard's teaching and interview responses are presented in the following sections.

Conceptions about Teaching

The analysis of classroom observation data and Bernard's interview showed that he held two dominant conceptions about teaching; "seeing himself as a teacher of students rather than a teacher of physics" and "helping students to think and become logical thinkers." The first conception about teaching was formed during his teaching days in his first school. This happened at the time he decided to teach physics when there was a shortage of staff to teach the subject. This conception was further consolidated in his present school. The second conception about teaching was shaped by one of the professional development programs he attended in Wellington when he moved to his present school. Further details about this are presented under the section Professional Learning Experiences.

Seeing himself as a teacher of students rather than a teacher of physics. According to Bernard, his job as a teacher was to help students reach their potential and the subject he was teaching was of secondary importance. He was quite happy to teach physics, chemistry, biology or mathematics as long as he could help students to reach their goals. He claimed that whenever he was asked "who are you and what do you teach?" his response had always been "I'm a secondary teacher, and I teach students." He felt that seeing himself as a teacher of students had contributed to his success as a teacher because he had been able to improve upon his teaching practice and increase his content knowledge across disciplines. Thus, he preferred to be called a teacher of students rather than a teacher of physics. According to Bernard, he had been successful in teaching physics because he realised he could make more difference in the students' lives than just being a teacher of a subject.

Helping students to think and become logical thinkers. In addition to seeing himself as a teacher of students, Bernard believed that effective learning included the development of the skills and the ability to ask and solve deeper level thinking type questions, rather than the superficial remembering of facts and figures. He thought that as very few of the students would actually use the physics they learn at school, he would like to expose them to activities that would make them think and find out things for themselves rather than feed them with content types of information. He commented:

I think giving students the ability to think deeply about things, ask questions, solve problems, I would define as an effective teacher or learner. The whole logical thinking skills and things is something we have to really push.
(Bernard)

He further mentioned that people with a physics background who are working in financial institutions and other sectors are often there because they are able to think logically in unfamiliar contexts, not just because they are familiar with something such as AC circuit theory. Bernard would prefer having students in his classes engaged in activities that help make them logical thinkers. Analysis of classroom observation data showed that almost each week Bernard's students were engaged in at least one such activity where they formulated their own design to solve a given problem.

Classroom Practices – Teaching Approaches

In this section, the teaching and learning practices and approaches that transpired in Bernard's classroom are highlighted. Also, the section examines how the conceptions about teaching held by Bernard were reflected in his teaching practice.

Like the other teachers, Bernard generally started his lessons by reviewing students' knowledge about what had previously been done on the topic. Most of the time this was done by projecting or writing a question on the board for students to solve. The teacher and students would then undertake the tasks/activities designed for the lesson. Lessons normally ended with Bernard reviewing the key points for the day's lesson.

Data from six classroom observations of lessons on Mechanics, and Electricity and Magnetism showed that Bernard's approach to teaching of physics was similar to the other teachers. Variation in terms of the use of the teaching methods was certainly the unique characteristic of Bernard. He used problem solving, simulations, demonstrations, discussions and teacher-centred instruction, with the latter being the dominant teaching method. Two main types of lessons were observed – those that involved practical work for students and those that did not (normal lecture-type lesson).

In the normal lecture type lessons, at least three different types of teaching method were most often employed. Such lessons normally started with a video presentation or computer animation on the topic to be taught. He would then lecture for about 10 to 15 minutes, and providing detailed explanations, especially about numerical physics problems. This was then followed by problem solving where students were supposed to apply the principles to physics problems from their workbooks or questions projected on the screen. Sometimes, Bernard used pre set-up experiments to demonstrate and illustrate the concept being taught. In almost all the lessons, summary notes were projected on the screen for students to copy.

Students' participation in the lessons was strongly encouraged. Rather than always introducing content material via lectures, Bernard organised exploratory activities for the students to carry out. The predict-observe-explain strategy was most often used to obtain students' responses on the concept before demonstrations were performed. Activities that fostered

collaboration were embedded in the teaching to engage students and these promoted student participation in the lesson. Asked how he managed to select such activities to fit within the time constraints, Bernard explained, during the interview, that making physics relevant and interesting to the students, while keeping an eye on the prize (which according to him, was successful NCEA or scholarship results), was a priority for him. He claimed that the collaborative activities were relevant and essential to make the subject more interesting to learn. They were considered essential to make the students become logical thinkers, a conception he held about teaching.

Though Bernard tended to fall back more on the traditional type of lecture, he tried to keep these short. Most often, he included humour in his teaching and shared jokes with the students, just to keep them relaxed and to put smiles on their faces. Asked why the traditional type of lecture method appeared to be dominant, Bernard explained that it had been a constant struggle for him, i.e. how do you keep the learning going if he was not directing it all the time. It seemed to him that students' achieved more when he lectured than letting them explore by themselves. He commented:

“...sometimes they can work quite hard when I’m standing up the front teaching, but when it comes time for them to be working independently I think the output can come down a bit. (Bernard)

The conception he held about teaching as “helping students to think and become logical thinkers” was mostly demonstrated in the practical lessons. Bernard admitted that the physics course itself was almost an “historical science course”. He stated that the course could be more mathematical and boring to students if care was not taken. Therefore, using teaching and learning practices that would keep physics relevant and interesting to the students was his main concern. In view of this, he had developed weekly student-designed investigations (called Physics

Olympics) as a form of competition for the students. In this weekly practical work, students were provided with a physics problem which required them to design their own method to investigate a problem and come up with the solution. The tasks were carried out in groups of three and four and active participation was encouraged.

Each group had between 25 to 30 minutes to investigate the problem. Together with the students, Bernard always spent a reasonable amount of time discussing the technical aspect of completing the task and the scientific ideas (or the interpretation of the findings) with the students. Each group had an opportunity to present its findings. The group that had the correct answer and/or an answer closest to the actual answer, won the prize. The group was also awarded a high score of 4 points and at the end of the term, the group that emerged with the highest score was given a plaque. During the post observation interview, Bernard indicated that the Physics Olympics was a competitive and fun way to introduce physics concepts to the students, especially to the Year 12 students who had just started high school physics.

Though Bernard perceived the constraints of an examination at the end of the year as a problem, he believed that he could still get students to think deeply and achieve well in the examination by thinking more about the problems that they had to work through. Bernard did not want to become a teacher who was “very dry and just got through the curriculum by always teaching in the old way of doing it”. He preferred to think through what the students needed to know or be able to do, as well as identify the skills that he thought were important and that could be taught through physics. He commented:

I'd like to think that, I've got miles to go, trying to reflect an older subject like physics being taught in a more modern way and which is at least cognisant of some neuroscience and neuroscience research. (Bernard).

Factors Constraining the Quality Teaching of Physics and the Low Numbers

According to Bernard, there are a number of challenges associated with the quality teaching of physics, and he asserted that the main ones are the physics curriculum, the alignment of the curriculum and NCEA achievement standards and lack of qualified physics teachers. He compared the physics curriculum to that of biology and commented that the biology curriculum now had many modern and interesting developments incorporated into it, whereas physics consisted of essentially pre 1905 content. This according to him has made physics almost an “historical science course” which could be quite dry and boring.

We don't do a great deal of modern physics, and modern physics is defined as anything that happens after 1905, so I think as a science we're lagging behind other subjects. Biology has got genetically modified organisms, and our students are learning and getting excited about it. Physics, we're doing Newton's Laws, which happened in 1666. (Bernard)

He added that only passionate, committed and dedicated teachers who love the profession of teaching would go the extra mile to select and design appropriate teaching strategies to keep the subject relevant and interesting. He stated: “you need to attract those people that see themselves as teachers”.

Bernard welcomed the news several years ago about the curriculum realignment (standards alignment by NZQA and expected changes to the physics curriculum). He expressed disappointment that little happened and asserted that what they got was just the same thing that they had before. He commented:

I think this country missed an opportunity with the realignment of standards. I think we could have used that as an opportunity to make our subject more

relevant and personable and things like that. I certainly know there are parts in there for investigation but the external examination was kept pretty traditional, I think we missed out on an opportunity with that. (Bernard)

Bernard considered that the standard of physics teaching had fallen due to a lack of qualified physics teachers. He indicated that, as a Head of Science and Physics, he would find it difficult to get physics teachers, as most of them were like him and had come from another discipline. He strongly believed that the problem of recruiting qualified physics teachers meant the numbers involved would continue to drop. He commented:

We still find it difficult to attract quality physics teachers...and if you have trouble recruiting then the standard of teaching will diminish and you will continue the cycle of dropping numbers. (Bernard)

Ways for Improving Physics Teaching and the Numbers Involved

Bernard made reference to the training of more physics teachers. He asserted that more qualified teachers are needed now more than ever before to teach the subject. He explained that if the students do not have quality teachers in front of them teaching physics, i.e. if they are taught by teachers who “struggle at times with the content” then the students would always see physics as a bit dry and boring and wouldn’t be interested to pursue it further. Bernard shared a similar view to that expressed by Nick and Vicky that those teachers who have been recruited from another discipline need more content preparation through professional learning courses to develop their skills and improve their content knowledge. He referred to himself as an example of a teacher coming from another discipline and credited his success to professional learning that he had undertaken.

I only have Stage I physics in my degree, so I've had to work quite hard with some of the content in Level Two and Three physics. (Bernard)

Mentoring and teacher collaboration were other ways that Bernard believed could help improve the quality teaching of physics. He would value a mentor, someone he could ring up to discuss his difficulties regarding a particular unit or concept he was struggling with. He asserted that mentoring and collaboration were important so that teachers don't teach incorrect concepts to students. Hence, he requested that a good support mechanism for physics teachers be put in place. Again, Bernard reiterated that society has not made teaching a particularly attractive career choice and until that situation changed, there would be little or no change in the number of graduates (including physics graduates) wanting to join the teaching profession. He opined that "the pay scale doesn't always reflect the amount of work we do". He was emphatic that graduates could earn more money in business, engineering, medicine and finance and hence he could not see many of them wanting to become teachers.

Professional Learning Experiences

As mentioned earlier, Bernard, was a biologist who switched to teaching physics and he had been successfully teaching physics for the last 25 years. He considered that professional development had played a vital role in his career. Most of Bernard's professional development had been school initiatives, personal reading, and attending conferences. He indicated that the school organised professional learning courses for its staff on a regular basis, but this had always been quite general and tended to focus more on pedagogy, literacy or the use of ICT. With regards to personal reading, Bernard claimed that he had constantly undertaken self-study or teaching as inquiry (Timperley, 2001), reflecting upon his teaching practices in the classroom. He emphasised that this form of professional learning had been beneficial to his teaching and that he had been

able to develop most of the teaching resources for the department by himself, with colleagues in the department using the resources in their own teaching.

Another form of professional development which had impacted positively on him was attending conferences. As Bernard put it, “trying to be more effective as a teacher” was one of his main objectives. He had therefore been to a number of conferences and science teachers’ meetings and through those conferences and meetings, he had connected with other physics teachers who he had contacted for support and ideas when there was the need to do so. He remarked:

I try to go to those as much as I can, and I find they’re very valuable. I find they’re invigorating, you get some good ideas, you get to network with other physics teachers and they’ve been great. (Bernard)

He referred to one particular conference he attended in Wellington as one of the best professional development courses he had ever attended. He consequently referred to it as a “thinking conference”. According to him, the conference had some of the top people in the world talking about thinking, and the experience had really changed his ideas about why he should be teaching physics and what he should be teaching. He further described a session he attended on cognitive overload where he learnt about not overloading students with content information in a lesson. He indicated he had embedded these ideas into his teaching practice and claimed this had yielded positive results. In fact, it was this particular conference that shaped Bernard’s second conception about teaching, helping students to think and become logical thinkers.

Overall, Bernard described the professional learning courses he had attended as “valuable” and mentioned that he felt lucky he had a school that valued professional development. He stated:

I’ve got the advantage that our school values professional development. I think that it’s kept me enthusiastic, it’s kept me wanting to improve, it’s kept me

wanting to do better, it's kept me questioning my own technique in the classroom, more than just the straight teaching of physics. (Bernard)

Findings from Bernard's Students' Focus Group Interview

There were about 65 students in total in all of Bernard's classes and of this number, 33 consented to participate in the focus group interviews. Six focus group interviews (with a minimum of 5 and a maximum of 6 students in each group) were therefore planned for. However, after the analysis of the fourth group no new themes were emerging, indicating that a "theoretical saturation" (Lewis-Beck, Bryman, & Liao, 2004, p. 1122) had been reached. A total of 22 students were therefore interviewed. The students interviewed in Bernard's class stated that they enjoyed physics lessons, especially the experiments they had been doing. Almost all of the students said that they enjoyed physics lessons because the teacher (Bernard) was a dynamic and passionate teacher and made the subject interesting and enjoyable to learn. The Year 12 students commented that they had not enjoyed physics in their previous years until they had a teacher who was enthusiastic and had interesting life experiences that he could relate to physics. One of the students stated:

He [the teacher] definitely had a lot to do with how much you enjoy physics. I think it's good to have a teacher who is generally pretty good and makes you understand it more. We are doing stuff (which is Physics Olympics) which is far more interesting and interactive. (Boy, Year 12)

Though they enjoyed physics lessons and liked studying physics, about 40% of the students observed that physics could be frustrating and a difficult subject to study if one could not understand the concepts. Again, the students were happy with their performance because they were achieving good results. They believed that they were going to excel in the end of year of

examination, despite one or two challenges that they identified, because they received good feedback from the teacher about where they went wrong and how they could perform better. They indicated that Bernard always pushed them in the right direction and never criticised them. In addition, he would occasionally test them to help identify their strengths and weakness, in comparison with everyone else, so that they could know their class standing.

Similar to the students in the other schools, the physics students in Bernard's class cited content, mathematical formulae and equations, and inadequate pre-requisite knowledge as factors that made physics difficult to learn. The students in the focus groups observed that there was a lot of content to learn, especially for the electricity topic. They also observed that many concepts were closely related and built upon each other, making it hard to fully comprehend other parts of a topic if previous ones had been missed. About 90% of the students also stated that remembering all the formulae and equations, and sometimes finding the correct equation and then applying it to a question was difficult. Memorization was difficult for many of the students. One student commented:

Remembering the formulas is always difficult because sometimes you get them muddled up. It is a difficult task to commit all these formulas into memory.

(Girl, Year 13)

Again, the students stressed that senior physics required an appropriate pre-requisite knowledge in order to understand the content. The Year 12 students in particular, emphasized that a lack of appropriate pre-requisite knowledge made it difficult to learn and understand many of the concepts taught. They indicated that over simplification of what they actually needed to know at lower science course level made physics difficult to learn at senior level. Nevertheless, they added that it was very satisfying once they had understood the concepts. They were therefore optimistic that

things would get better as they progressed through the course because they had a good teacher who would make the subject easier to understand.

Responding to the question about how they would like their physics teacher to change his teaching style or changes that might make physics more interesting to learn, almost all of the 22 students indicated that they were happy with the way physics was taught and that they wouldn't want any changes to occur. They were particularly happy with the video presentations, the practical work, the discussions they had in class, problem solving and the fact that the teacher did not follow a fixed lesson plan. They believed that Bernard was making physics interesting to learn, thus, they were comfortable with his teaching style. According to the students, practical experiments that Bernard conducted helped to explain things at a visual level and they would like more of these.

Although the students seemed satisfied with the teaching approaches, a particular change they wanted was to either individually or as class, create something (for example a robot) using the physics knowledge they had. They observed that it would be fun and interesting to transform the knowledge they had gained from the hands-on-activities into a creative activity. One student stated:

...creating something that uses the knowledge that we have in a practical way.

I actually saw this thing at MIT where they got given coils of wire, a piece of wood and a magnet and they had to make a motor out of it and some people got their motor to go thousands of cycles per minute, it was incredible, it was pretty interesting. (Boy, Year 13)

Why Students would or would not Become Physics Teachers

All of the 22 students in the focus groups stated that they would not take physics at university unless it was a prerequisite for something else, a view expressed by most of the students from the other schools. Only two students in these groups showed an interest in the teaching profession and indicated that they might be willing to become physics teachers. One of the students mentioned that physics would be one of the subjects he would consider teaching because it was not just writing on a whiteboard and telling the students what to do. Rather, there were a lot of practicals, which would make the subject and the job more interesting. The reasons cited by the remaining 20 students in these groups who would not consider becoming teachers were no different from those given already by students in the other schools. They preferred to take physics-enriched courses that would lead them into more rewarding, respected and well-paying jobs such as engineering and medicine.

Summary of Case Studies

The summary of the case studies is presented in Table 28. The main findings related to conceptions about teaching, teaching approaches, constraining factors and ways for improving upon physics teaching and learning and the number of students (and possibly teachers) involved are highlighted. Also included in the table are the teachers' qualifications and length of time of their teaching experience.

Table 28: Summary of Case Studies

Characteristics/Case names	Philip	Nick	Vicky	Bernard
Qualification	Physics graduate and also holds a Graduate Diploma.	PhD in Physics and also holds a Graduate Diploma.	Physics graduate and also holds a Graduate Diploma	Master of Science (Marine Biology), Bachelor of Science and Graduate Diploma
Teaching Experience	30+ years.	12 years.	10 years.	25 years.
Conception about Teaching	Getting students engaged. Establishing a good relationship with students.	Telling the history of Physics to make students see how things developed. Providing learning opportunities for students to help themselves and help others.	Students learn by doing activities. Creating an atmosphere of togetherness. Giving students content knowledge and detailed explanations.	Seeing himself as a teacher of students rather than a teacher of Physics. Helping students to think and become logical thinkers.
Teaching approaches	Practical demonstration, Problem solving, Collaborative learning, Simulations, Lecture method.	Predominantly lecture with note-taking from PowerPoint, Problem solving techniques.	Hands-on activities, Collaborative learning, Interactive demonstrations, Lecture method.	Problem solving, Simulations, Demonstration, Discussion. Collaborative learning, Lecture method.

Constraining factors (Decreasing order of importance as indicated by the teacher)	Time constraints, Assessment demands, Alignment of achievement standards with the curriculum, Increased workload, Poor tuition of physics at junior levels, Mathematical incompetency on the part of students.	Lack of time, Dichotomy between curriculum and assessment, Assessment demands and teacher work load, Inadequate qualified physics teachers, Public perception about physics, Nature and structure of junior science.	Premium on high stakes assessment, Time constraints, Assessments requirements, Alignment of achievement standards with the curriculum, Teacher workload, Nature of the physics curriculum Poor public perception about teaching profession	Lack of qualified physics teachers, Alignment of the curriculum to the NCEA achievement standards, Students' preoccupation with assessments, Physics curriculum itself.
Way forward for improving upon physics teaching and learning	Reduction in the number of assessments, Reintroduction of a single internally assessment standard, Improved remuneration and status of teachers, Provision of professional development opportunities for teachers.	Allocation of more time, Re-alignment of achievement standards and curriculum, Encouraging postgraduate physicists into teaching, Provision of professional learning courses, Better remuneration.	Reduction in NCEA assessment requirements, Provision of better remuneration package for teachers, Provision of professional development courses for teachers.	More qualified physics teachers, Content preparation through professional learning courses, Mentoring and teacher collaboration, Provision of good support mechanism for teachers and better remuneration, Allocation of more time for teaching.

Differences and Similarities between the Cases

Conceptions about Teaching

As indicated in Table 28 the classroom observation of the four teachers and post observation interviews revealed the conceptions which underline and underpin their teaching careers. All of them, with the exception of Vicky, held two main conceptions about teaching. Vicky held three main conceptions. Bernard's conceptions of teaching were seeing himself as a teacher of students first and foremost rather than as a teacher of physics and helping students to think and become logical thinkers. Nick's conceptions were about the importance of telling the history of physics to help students see how discoveries developed and providing learning opportunities for students to help themselves and help others. Philip believed in getting students engaged and establishing a good relationship with them. Vicky opined that, students learn by performing activities, and that it was important for her to create an atmosphere of togetherness and giving students content knowledge and detailed explanations. The dominant conception about teaching, held by the participants, that can be inferred were to help students to be able to think for themselves, so they would become useful to themselves and society at large.

Teaching Practices

Analysis of classroom observation data showed that Philip used a variety of teaching methods to engage his students, which included practical demonstrations, problem solving and lecture methods. The predominant instructional method was lecture and problem solving, nonetheless videos and the use of interactive demonstrations were also used as and when necessary. Philip placed an emphasis on collaborative learning by encouraging students to work on physics problems in groups. For Nick, there was not much variety exhibited during the lessons in terms of teaching methods. Lessons were predominantly characterized by activities such as exercises from the workbook (and textbook) and copying notes from PowerPoint slides. Collaborative learning was not strongly promoted and students often worked individually on physics problems. However,

there were indications of collaboration during some of the few practical sessions observed, with students working in groups of three and four. Limited availability of equipment may explain why he allowed students to work in groups during practical lessons.

The lessons that were observed in Bernard's classes showed that he used problem solving, simulations, demonstrations, discussions and teacher-centred instruction, with the latter being the dominant teaching method. Similar to Philip, two main types of lessons were observed for Bernard – those that involved practical work for students and those that did not. Bernard placed emphasis on collaborative learning by encouraging students to work on physics problems in groups. Lessons usually began for Vicky's classes with her outlining the activities/objectives to be undertaken on the white board. Students' previous knowledge is reviewed orally. The day's lesson is then introduced and students are taken through the activities outlined on the board. PowerPoint presentations accompanied with white board illustrations and videos were a common feature in all the lessons observed in Vicky's class. Similar to Nick, there was no organised practical lesson on its own but practical activities ranging between 10 to 20 minutes were incorporated into the lessons.

Case studies by their very nature imply individual responses to decisions about teaching and learning, nonetheless, the teachers in the present case study were somewhat similar in terms of classroom practices reported in the survey. Even though they all hold constructivist view of teaching and learning to a considerable extent, their approach to physics instruction is content-oriented, because of the nature of the assessment. Concerns about content predominate planning and reflections about students' perspectives play rather a minor role.

Constraining Factors

There was a general consensus among the teachers that the major constraint to quality teaching of physics was assessment. As asserted by all the respondents, the dichotomy between teaching and assessment criteria, time constraints due to the increased workload that changes to

assessment practices imply and a lack of qualified physics teachers seemed to be the major factors constraining the quality teaching and learning of physics in the high schools.

According to Bernard, there are a number of challenges associated with the quality teaching of physics, the dominant ones being the alignment of the curriculum and NCEA achievement standards, the physics curriculum, and the lack of qualified physics teachers. The conflict between the curriculum and the assessment, time constraints, and teacher work load were the major obstacles to the quality teaching and learning of physics according to Nick.

The availability of teaching and preparation time was the foremost constraining factor for Philip, together with the alignment of achievement standards with the curriculum. Internal assessment has placed additional workload on teachers and reduced the time available to spend on physics teaching and improving upon the better approaches to teaching of physics instruction. Philip further explained that NCEA has dominated professional learning for physics teachers for far too long, i.e. implementation, moderation, changes to standards and alignment, and he felt that this had decreased the emphasis on the quality teaching of physics.

Similarly, assessment was the greatest constraining factor for Vicky, as students were concerned with the accumulation of credits rather than learning, which is contrary to the 2007 *NZC* which gives schools the scope, flexibility and authority to design and shape their curriculum so that learning and teaching is meaningful and beneficial. With assessment becoming more difficult, teachers have to use more time preparing students for them. She further lamented as long as students had to be assessed by NCEA examinations, teachers were not going to be able to implement the aspirations of *NZC*, which appeared to take second place to satisfying the demands of the NCEA assessment.

Way forward

There was unanimity among the respondents when it came to suggesting ways of improving physics teaching, raising the numbers of students studying physics and increasing the numbers of physics teachers in the future. All the respondents wanted to see more time allocated to the teaching of physics, a reduction in the assessment requirements, and the provision of professional learning courses for non-specialist teachers intending to teach physics. A better remuneration package for physics teachers was also suggested.

Apart from the above suggestions, which all the respondents agreed upon, Bernard also suggested mentoring and teacher collaboration were other ways to help improve the quality teaching of physics. Philip also was of the view that improved access to teaching resources and laboratory assistants was needed. On assessment, Vicky was of the view that to improve the teaching and learning of physics and increase the numbers of students taking the subject, the emphasis on high stakes assessments in Year's 11 to 13 should be avoided so that teachers could spend more time teaching and helping students to learn.

CHAPTER 6

DISCUSSION

In this chapter, the findings from the study into the teaching and learning of physics in New Zealand secondary schools are presented and discussed in relation to the research questions that were formulated to guide the study. The findings are discussed based on the quantitative and qualitative data that compared the responses of participants – teacher educators, high school physics teachers and students, who participated in the study. The qualitative data gathered are used to complement and substantiate survey findings. Below are the research questions that guided the study and this discussion:

1. What is emphasised in the initial education of high school physics teachers in New Zealand and why?
2. a. What are the conceptions about teaching held by New Zealand high school physics teachers?
b. How are these conceptions reflected in their teaching practice?
3. How do secondary teachers and students perceive their physics classroom interactions?
4. What on-going professional learning do the teachers receive, if any, and how effective are they, for the teaching and learning of physics?
5. What factors, if any, do teacher educators, secondary teachers and students perceive as constraining the quality of teaching and learning of physics in New Zealand?
6. What changes do teacher educators, secondary teachers and students perceive need to occur to make physics more interesting to learn?

Teachers' Perceptions of their Initial Teacher Education

Prospective teachers enter initial teacher education programmes with different backgrounds, experience and knowledge. This means that beginning teachers will have varying degrees of need to prepare them to be effective in their professional career. The physics teachers in this study indicated the extent to which their ITE prepared them to become effective teachers, i.e. how to reflect on minds on approaches to teaching the various physics topics currently taught in New Zealand high schools. The findings in Figure 6 showed that physics was a first-choice teaching subject for about three quarters of the teachers who participated. These findings suggest that the majority of New Zealand physics teachers specialised in physics and therefore completed traditional undergraduate physics courses. It was also found that more than a quarter of the physics teachers had a subject major other than physics in their initial degree and therefore initially undertook teacher education in a different subject area. Their change in discipline was due to a shortage of physics specialists or because an opportunity arose to teach physics.

Knowing the tertiary-level educational background of teachers provides useful information about their preparation for their chosen career. Also of importance are teachers' perceptions of their preparation, i.e. how well teachers feel they are prepared to teach the various content areas. The National Research Council (1996) recommends that teachers of science and mathematics have a firm grasp of science and mathematics concepts because the responsibility lies on the teachers to guide students to explore these concepts. Research findings however, show that it is difficult to measure the extent to which a large national sample of teachers understand the concepts they are teaching, hence proxy measures such as 'major' or 'number of courses taken' in one's field are usually used (Banilower et al., 2013; Weiss et al., 2001). The findings in Figure 6 show that the majority of the teachers specialised in physics and this gives an indication that the teachers are likely to have a firm grasp of physics concepts.

Table 6 provides more detailed information on physics teachers' perceptions of their preparedness to teach each of the content areas in the curriculum. Though the majority of the teachers completed the traditional undergraduate physics courses, the physics teachers considered themselves not well-prepared in some content areas, including electronics, modern physics and nuclear and atomic physics. Similarly, tests of between-subject effect presented in Table 10 showed that the only construct of the UTL model to reach statistical significance was that for subject matter knowledge. The content areas investigated in the survey were largely based on the current 2007 New Zealand Curriculum (NZC) (Ministry of Education, 2007), however, some of the teachers completed ITE some years ago when concepts which are now core parts of the curriculum may not have been emphasised in teacher education programmes. This may explain the respondents' weaknesses in other content areas, as presented in Table 6.

On the other constructs of the UTL, especially knowledge of teaching, a large proportion of the teachers indicated that their ITE did not incorporate the use of technology into physics teaching and more than a quarter of the teachers thought that their pre-service education did not focus on the use of inquiry and problem-based approaches as well as information on assessing students' learning. These aspects of physics teaching were in the past not considered as important as they now are and this may explain these findings. The estimated marginal mean score of 3.94 recorded by the 2008+ (Table 11) completing year group reveals that current ITE programmes are performing better in this respect.

The physics teacher educators, who participated in the study, thoroughly discussed the course structure, content components and what is emphasised in their physics education courses. The components and nature of the physics education courses vary across the Colleges of Education in the universities in New Zealand but all focus primarily on the development of pedagogical content knowledge and the practical aspects of teaching physics. They do not emphasize subject matter content knowledge.

The entry qualification to the physics education courses is a physics degree or successful completion of one or more Stage 3 physics papers. All, or at least part of a traditional undergraduate physics course has to be completed to meet this requirement. The traditional physics course in New Zealand at undergraduate level comprises a blend of theory (e.g. mechanics, waves, optics, heat, electricity and electromagnetism, nuclear physics) and laboratory work, similar to what is reported internationally (Banilower et al., 2013; Korthagen et al., 2006; McDermott, 2001; McDermott & Shaffer, 2000; Weiss et al., 2001). The content knowledge physics teachers gain arises mainly from their participation and learning in this undergraduate programme.

The traditional approach to teacher education (generally, not just for physics) has been criticised for its limited relationship to student teachers' needs (see for example Cochran-Smith, 2005; Darling-Hammond et al., 2002; Korthagen et al., 2006; McDermott, 2001; McDermott & Shaffer, 2000). After analysing the effective features of teacher education programs in Australia, Canada and Netherlands, Korthagen et al. (2006) for example, outlined how to guide the development of teacher education programs that are responsive to the expectations, needs and practices of pre-service teachers. The authors recommended seven principles called "principles of practice" (p. 1039) to those teacher educators willing to accept the challenge of reconstructing teacher education from within.

Etkina (2010) and Hodapp et al. (2009) have outlined the features of a successfully implemented new model of teacher preparation and recruitment. At the University of North Carolina, Chapel Hill, the model (programme) requires a student to complete a science major with a teaching qualification in four years (Hodapp et al., 2009). At Rutgers University, Etkina (2010) reports that the model centres on three aspects of teacher preparation – content knowledge of physics, knowledge of pedagogy and knowledge of how to teach physics (pedagogical content knowledge). Among other things, students in these programmes: learn physics through the

pedagogy that pre-service teachers need to use when they become teachers, learn how the processes of scientific inquiry works and how to use this inquiry in a high school classroom for specific physics topics, learn what students bring into a physics classroom and where their strengths and weaknesses are, engage in scaffolded teaching in reformed courses before doing student teaching or starting independent teaching, and form a learning community (Etkina, 2010, pp. 21-22). Findings from the Teaching and Learning International Survey (TALIS) 2013 results indicate that teachers whose initial education included content, pedagogy and practice elements specifically for the subjects they teach reported feeling better prepared for their work than their colleagues without this kind of training (OECD, 2014). The philosophy and coursework for this model can be adapted by stakeholders who are committed to physics teacher preparation.

The finding that New Zealand physics teacher educators in their respective Colleges decide what content to include in their physics education courses aligns with the assertion by (McGee et al., 2010) that teacher educators in New Zealand generally continue to have divided opinions over the subject matter knowledge that should be included in teacher education qualifications. That is, there is no national teacher education curriculum, which means that different teacher education providers can prepare teachers differently. There is, however, oversight of the ITE process by the New Zealand Teachers Council and there are generic Graduating Teacher Standards (New Zealand Teachers Council, 2010) that need to be met by new teachers graduating from teacher education programmes.

Teachers' Conceptions about Teaching

Formation of Conceptions

Some studies about teachers' conceptions, beliefs and/views draw conclusions about teachers' practice but the conclusions are not based on observational data (Hashweh, 1996; Tsai, 2002). Recent studies about teachers' beliefs that included classroom observations found a relationship between beliefs about teaching and learning science and their epistemological beliefs and their

teaching practice (Ladachart, 2011; Mulhall & Gunstone, 2012; Tsai, 2007). In this study, the conceptions, beliefs, and/or views held by four exemplary physics teachers have been identified and compared. The study also illustrated some possible relationships between these conceptions and the teachers' teaching practice. It is evident in this study that these conceptions about teaching held by the various participants had developed over a number of years. This outcome of the study supports Ladachart (2011) who found that physics teachers developed conceptions about teaching based on their previous experiences at school, both as students and as pre-service teachers.

Relationship between Conceptions and Teaching Practice

The relationship between the teachers' conceptions and their teaching practice is observable. For example, Nick, who holds a conception of telling the history of physics to make students see how discoveries developed, often tells his students the history of physics and stories about scientists, when he considers it as relevant to the concepts being taught. Also, Bernard, who holds a conception of helping students to think and become logical thinkers, spends time engaging students with activities where the students find their own solutions to problems. This finding of the study is in line with Koballa et al. (2005) who claim that teachers conceptions about teaching can serve as reference points for their teaching practice.

A study by Tsai (2007) of four teachers and their students that included classroom observation data found consistency between the teachers' conceptions about teaching and their teaching practice. Similarly, Mulhall and Gunstone (2012) used qualitative methodology to explore views about physics held by a group of physics teachers whose teaching practice was traditional, and compared these with the views held by physics teachers who used conceptual change approaches. Mulhall and Gunstone's study of 10 teachers (5 in each group) found that the teachers taught physics in a manner which was consistent with their views about teaching and learning of physics. Findings from this study on teachers' conceptions about teaching are also in line with those of Mulhall and Gunstone (2012) and Tsai (2007).

As indicated by Koballa et al. (2005), Ladachart (2011), and Tsai (2002) the context (conditions) in which teachers teach can have an influence on their conceptions about teaching and the extent to which these conceptions are practiced in the classroom. Buaraphan (2007) argues that conceptions about teaching are often resistant to change. Nonetheless, contextual constraints may cause teachers to compromise or back-up their lived-long conceptions about teaching (Buaraphan & Sung-Ong, 2009; Friedrichsen & Dana, 2005; Koballa et al., 2005). As presented in this study, Nick and Vicky have a set of strongly-held ideas about teaching, including “providing learning opportunities for students to help themselves and help others” and “students learn by doing” respectively. However, both have compromised their beliefs about teaching due to contextual constraints. Lack of time and the demands of the curriculum rendered Nick’s desire of minds on approaches to teaching and learning for students to help themselves and help others, practically impossible to implement. In the case of Vicky, as she has been teaching in a new school where she has experienced the discordancy of her previously developed and held conception (students learn by doing), within the new context where achievement in external high stakes assessment is the key motivator has led to the formation of a new conception about teaching (i.e. feeding students with content knowledge and detailed explanations).

Nick and Vicky’s cases are analogous to Philip but contrast with Bernard’s, where, under the same contextual constraints, he continues to teach and selects instructional approaches consistent with his ideal and aspirational conceptions about teaching, as well as including content knowledge instruction. The findings support the assertion that the context in which teachers teach can not only affect their conception (Koballa et al., 2005; Ladachart, 2011; Tsai, 2002) but also their teaching decisions. The findings that Nick, Philip and Vicky compromised their ideal conceptions challenge the assertion by Buaraphan (2007) that conceptions are often resistant to change. The findings however, agree with the claim by Ladachart (2011) that contextual constraints may cause teachers to compromise their ideal and aspirational conceptions about teaching, leading to the

formation of new ones. On the other hand the finding that Bernard did not compromise his ideal conceptions supports Buaraphan's claim.

Physics Classroom Interactions

Teaching Approaches

The findings from this study conducted with a wide range of physics teachers throughout New Zealand align with those of other international studies. The findings indicate that physics classroom dialogue tends not to support constructivist epistemology or inquiry based teaching and learning, which is emphasised in the *NZC* (Ministry of Education, 2007). Thus, what is occurring in the physics classrooms is contrary to the aspirations of the *NZC* (Ministry of Education, 2007). The classroom observations also suggest that teachers did not embrace or align with the cognitive apprenticeship model (CAM) which suggests that learners should be exposed to the teaching methods that give them the chance to observe, engage in, invent, or discover expert strategies in context (Berryman, 1991; Collins et al., 1991).

The CAM stresses that teaching methods should systematically encourage student exploration and independence and that teachers should only coach – “offering hints, feedbacks, and reminders; provide scaffolding (support for students as they learn to carry out tasks); and fade gradually, handing over control of the learning process to the student) (Berryman, 1991, p. 5). The teachers' survey data, as presented in Table 12, revealed that student-centred instructional approaches were not common in many physics classes. In most cases, teachers (across all decile rankings) decided on what happened in the senior physics classrooms and students' ideas and suggestions played little role in the planning of teaching and learning processes.

Students rarely had the opportunity to plan and implement their own designs for experiments as most often students carried out experiments by following pre-determined instructions from teachers. Students' questionnaire data and focus group interviews further corroborated the teachers' questionnaire data. As reported by (Berry, Gunstone, Loughran, and Mulhall (2001),

such an approach to teaching is an ineffective way of developing students' understanding of science concepts, and it also presents a wrong impression of how scientific knowledge develops. Students' responses matched with teachers' reporting that classroom instruction was teacher-centred. An examination of students' experiences, both from focus group interviews and survey data (Figure 12), in relation to what actually happened in their classrooms and how often they would prefer the strategies to be applied, revealed that students were dissatisfied with many of the teaching approaches used. Students wanted more student-centred classroom activities.

Similar findings were reported by Angell et al. (2004), Hackling et al. (2001), Masika (2011), Sunal et al. (2015) and Vosniadou (2007), where physics classroom teaching was dominated by teacher-centred approaches and chalk and talk instruction. Hackling et al. (2001) for example, reported that in many secondary schools in Australia, lessons were of two main types: practical activities where students followed the directions of the teacher to complete an experiment, and the chalk and talk lesson in which learning was centred on teacher explanation, copying notes and working from an expository text. In the late nineteen eighties in Australia, Tobin and Gallagher (1987) reported that the common instructional mode in high school science classes comprised of lecture presentations followed by individual seatwork.

The majority of the students in Angell et al.'s (2004) study indicated that they preferred more student-centred approaches tailored to their needs. This agrees with the views of the 82 students who participated in the focus group interviews in this present study, who stated that their interest in physics might be enhanced if physics lessons included small group work and discussions, where they might be given practice questions and time to discuss physics problems between and among themselves. In this way, they might be able to work off each other's strengths and weaknesses to achieve a better result.

The findings also add to the literature showing that the traditional teaching approaches, which often fail to promote student understanding in physics (Duit, 2009), still persist. The use of more

traditional teaching approaches for physics contributes to students' thinking that physics is a difficult and boring subject and not something they want to participate in further. Some students in this study took physics because it is a requirement for future qualifications such as for engineering or medicine, rather than because it was interesting *per se*. As many other authors have noted, physics would potentially be more interesting to learn through a range of more student-centred approaches and the incorporation of different approaches such as the use of modelling, animations and simulations for problem solving (Afra et al., 2009; Akerson et al., 2007; Campbell et al., 2011; Dünser et al., 2012; Pedersen, 2011; Tversky, Morrison, & Betrancourt, 2002; Ülen & Gerlič, 2012).

In their study, which investigated two different approaches to laboratory work using observations, interviews and a written survey, Berry et al. (2001) found that experiences provided by the teachers in the classroom had an impact on the thinking of the students. Students who were involved in the construction and communication of a design to validate scientific information developed a stronger sense of the ways in which their learning related to the broader context of scientific work. By comparison (among the case study teachers in this present study), Bernard's weekly Physics Olympic events created the platform for students to construct, design and communicate their own ideas to solve a given scientific problem.

The teachers (both survey and case studies) who participated in this study admitted that most students could not see physics as a relevant science because the subject was often taught in a way that did not connect physics concepts with everyday situations. They also conceded that physics teaching was often very traditional, using the chalk and talk approach. These findings align with the students' assertion that physics teaching is often "dry and boring". Teachers' love for and continual usage of this traditional instructional approach may be due to their own experiences at school, both as students and as pre-service teachers since teachers of science often teach in the way they were taught (Koballa et al., 2005; Ladachart, 2011; McDermott & Shaffer, 2000). What

is interesting is that teachers seemed to hold onto these ideas quite tightly even when they knew that students learn more effectively by doing. As noted by McDermott and Shaffer (2000), it appears that many physics teachers are unable to separate the physics they learnt from the way it was presented to them. These teachers might be thinking that it worked for them, so why not for their students?

As noted by the students (and supported by the teachers), physics is naturally not an easy subject and it involves multiple concepts and mathematics that can make it challenging for students. The responsibility lies with physics teachers to create an enabling atmosphere in their classrooms that would allow physics students to learn more and develop greater interest in the subject. Conner (2013) pointed out that changes to teaching methods, including collaborative learning, peer-teaching and student-student questioning strategies, are likely to have a positive impact on student learning. She observed that listening to students ideas about what they want to learn creates an enabling environment for them to learn effectively.

Likewise, as observed by Darling-Hammond and Baratz-Snowden (2005) and Smart and Marshall (2012), the range of information and thinking skills students may learn is largely influenced by the types of classroom practices adopted by the teacher and therefore the learning experiences they afford. Perhaps, if teachers used students' prior knowledge and thinking skills to a greater extent to inform students' learning, the students might show more interest in physics. Because learning is largely influenced by the way students interact in the classroom, it is important that they are assisted to learn through pedagogies involving full interaction, collective reflection and development of consensual knowledge (Conner, 2014a; Darling-Hammond & Baratz-Snowden, 2005; Moraru et al., 2011; Smart & Marshall, 2012). Physics teachers therefore need to design and implement instructional approaches, taking account of interactive and visual supports (Dünser et al., 2012; Pedersen, 2011; Tversky et al., 2002; Ülen & Gerlič, 2012), that allow students to learn from each other.

More so, students in the focus groups wanted teaching methods that supported active participation. The students called for more group activities, discussions, and hands-on activities which would create a platform to learn from each other's strengths and weaknesses to achieve better results. This may influence students' attitudes towards physics and may encourage them to pursue further studies in physics at higher levels of their education. Wistedt (2001) found that Swedish university programmes that succeeded in recruiting and keeping students were characterised by collaborative-based learning and methods that provided opportunities for interactions between students, and students and staff. This has an implication for high school physics education.

Use of Formative Assessment

The findings presented in Table 13 indicate that teachers in the survey perceived their response and assistance to students to be important. That is, most of the time, teachers in the survey showed an interest in their students' learning and provided the needed motivation and encouragement to students. However, formative types of assessment in classrooms, such as giving quizzes and providing feedback to show students how well they are performing rarely happened in all schools. Almost all of the teachers reported negatively on this item. Students also reported this in their survey. An examination of students' responses in Figure 13 shows that the majority of the students (about 90%) would like to have formative types of assessment so that they could assess how they were performing in the subject. This finding is comparable to the findings by Sunal et al. (2015) who reported that formative assessment was rarely observed in physics lessons in Alabama State as most often physics teachers resorted to the use of summative assessment.

As indicated by Black (1998) formative assessment is diagnostic in nature and it is intended to provide the teacher with feedback about teaching and learning processes. The results from formative assessment inform the teacher about students' performance abilities and the teacher uses the information to reform his/her teaching (Atkin et al., 2001; Darling-Hammond & Baratz-

Snowden, 2005; Shepardson & Britsch, 2001). The practice of formative assessment must therefore be integrated into physics teaching and learning since it's essential to quality teaching. As Conner (2013) explained, formative assessment also provides an indication of progress to both students and teachers and "assessment results provide valuable information that guide subsequent teaching-learning planning" (p. 157). Students in the survey for this study seemed to want more information about this than they were currently receiving.

Use of ICT

The advances in technology have provided a new platform for conceptual change and problem solving in physics teaching. These technologies come with visual supports and can provide students with an opportunity to interact with the virtual world. When students are actively engaged in learning in these ways, they are more likely to be interested and potentially learn more effectively (Dünser et al., 2012; Pedersen, 2011; Tversky et al., 2002; Ülen & Gerlič, 2012; Wieman et al., 2008). Findings from both the teachers' survey data (Table 14) and observation data however revealed that physics teachers in this study rarely used ICT tools for physics teaching. Students who responded to the survey questionnaire also confirmed the low use of ICT tools in physics teaching (Figure 14). This finding matches with other findings conducted in educational settings regarding the use of ICT to support teaching and learning (Eteokleous, 2008; Koehler & Mishra, 2009; Shih-Hsiung, 2011; Smeets, 2005). The authors asserted that effective teaching requires integration of both content knowledge, pedagogical knowledge and technological knowledge (Eteokleous, 2008; Koehler & Mishra, 2009; Smeets, 2005). Teachers' lack of use of interactive instructional approaches in physics classrooms on a frequent and regular basis may largely be attributed to the limiting factors (assessment demands, time constraints, teacher work-load etc.) identified by the teachers.

This revelation that teachers in New Zealand rarely use ICT tools to support physics teaching and learning is disconcerting and should be an area for future professional development for

teachers. It is possible that most of the teachers are not adequately resourced to use ICT tools, a situation one cannot blame the teachers for creating. Notwithstanding, Bernard and Vicky's case studies indicated that teachers of physics can really make a difference by being committed to what they are doing. In spite of the contextual constraints, these teachers (Bernard and Vicky) were committed to make the subject relevant and interesting to learn by employing various forms of visual supports, through technology usage, in their teaching. There were many more incidences of visual supports for student learning and wider range of pedagogies which incorporated ICT usage.

There is enough evidence to support the claim that pedagogical shifts driven by ICT can enhance the richness of learning environment (see for example Chandra & Watters, 2012; Dünser et al., 2012; Ülen & Gerlič, 2012; Wieman & Perkins, 2005; Wieman et al., 2008). As pointed out by Wieman and Perkins (2005, p. 40) "education research, careful measurement, and new technology make it possible to guide most students safely along the path towards a true understanding and appreciation of physics." Physics teachers therefore need to be supported to integrate ICT tools into on-going practices of teaching and learning. There are a lot of physics innovative approaches (and computer-based tools) out there which have proven to facilitate student learning. All these tools are available for teachers of physics to hook on so as to make physics teaching and learning more user friendly.

Teacher Support and Professional Learning

One way for improving science instruction is professional development (Banilower et al., 2007). Given the importance professional development plays in the education system, especially in the sciences, it is essential for stakeholders to investigate what kind of professional learning teachers need to help them to be effective practitioners. This study has provided important information about the kind of professional development physics teachers need to enhance their teaching practice. This study found that there is little or no organised form of physics professional development for teachers in New Zealand. As far as professional experiences are concerned, all

the teachers in the case studies expressed concern about the lack of physics professional development for teachers. Most of their professional experiences in recent years has been through teaching as inquiry (Timperley, 2011), using reflection of their teaching practices in their classrooms.

In the teachers' survey data (see Figure 10 and Figure 11), the teachers reported a significant need for professional learning related to deepening their own content knowledge, understanding student thinking in physics, the use of inquiry/investigation-oriented teaching strategies and the use of technology in physics teaching. This suggests that teachers need more content and pedagogical preparation or help to find ways to develop their competencies in these areas. This finding is in line with the OECD (2014) report that teachers now need to be prepared for a much broader range of tasks at all levels. The finding also supports those of Sunal et al. (2015) who contend that teachers must be provided with in-depth pedagogical content knowledge for each major physics concept area.

The findings in Table 17 show that physics teachers' cluster meetings were the main source of professional learning for the teachers. This aligns with the findings from the case studies. The case study teachers who were interviewed also expressed concern about the lack of professional development for physics teachers. Physics cluster meetings organised by UC Education Plus were the only professional learning they could remember. On-going professional learning can make an important difference in the experiences and capacities that these teachers have. Initial teacher education providers within Faculties of Education, as well as the Ministry of Education, could implement professional development programmes on a regular and frequent basis for these teachers to deepen their own content subject matter and pedagogical content knowledge. The teachers in the survey and the case study teachers all identified the need to be supported to become effective teachers, and there is an obligation for these institutions to implement practices and supply the needed resources to enhance the quality of teaching and learning of physics in schools.

Teachers need to develop their skills and practices in order to improve on their practices for the betterment of their students.

Findings from this study reveal that the provision of professional development on content and pedagogical knowledge are the perceived changes needed to improve the quality teaching and learning of physics in New Zealand. Professional learning programmes should support teachers to deepen their technological pedagogical content knowledge to make learning for their students interesting and relevant. Also, as indicated by (Scheerens, 2009), pedagogical content knowledge is about selection of topics, useful forms of presentation, analogies, illustrations, examples, explanations and demonstrations that make the learning of specific topics easy for learners, in other words, appropriating pedagogy to content. That is, in-depth knowledge about the content and pedagogy are crucial for teachers to effect learning.

Findings from the case studies show that continuous professional development in schools can sustain teacher improvement and development, thereby enhancing student learning. Continuous self-study or teaching as inquiry (Timperley, 2001), has impacted significantly on the case study teachers – e.g. Philip, Nick, Vicky and Bernard. Bernard's success story is highly connected to his self-study and participation in professional development opportunities where he connected with other physics teachers who he could contact for support and ideas. Philip had also undertaken teaching as inquiry to understand his own teaching practices, analysing tests, exams and experiments to find better ways to help his students with their learning.

As indicated by Bernard, physics teachers need to be supported through induction, mentoring, and teacher collaboration services so that they can stay on top of their job. This aligns well with Futernick (2007) and Hodapp et al. (2009), who reported that in the United States, strong collegial support had a significant influence on physics teachers who decided to remain in the classroom. As a form of support to teachers the PhysTEC institution in the United States have been providing induction and mentoring services to their graduate teachers through the use of experienced

teachers and/or teachers-in-residence (TIR) (Hodapp et al., 2009). What New Zealand can do is that physics departments in universities, physics teacher educators (Colleges/Schools of Education), NZIP and physics experts can among other things, collaborate and create a physics learning community among physics teachers, connect future teachers in the university programmes with practicing teachers and offer a forum in which practicing teachers can help improve the programmes at the university level. Many institutions and organisations in the United States have collaborated in this way and have achieved excellent results (Etkina, 2010; Hodapp et al., 2009).

Factors Constraining the Quality of Physics Teaching and Learning

Both the teachers' survey data and their open-ended comments corroborate the case study data which suggest that the major hindrance to the quality teaching and learning of physics is assessment and NCEA requirements. Evidence from this study has shown that physics teaching in New Zealand is driven by assessment. The assessment and its related paper work have taken most of the teachers' time that teachers would have otherwise used to prepare interesting lessons for their students. Findings from the survey data and the teachers' interviews suggest that the teachers are always under pressure to complete assessment tasks (achievement standards for NCEA), therefore there is little or no time to personalise learning experiences for individual students. The standards themselves are content focused and the assessment system for physics values recall of content knowledge, so this is what teachers focus on. All the case study teachers mentioned this and thought that the realignment of the NCEA standards with the new curriculum (Ministry of Education, 2007) was very disappointing.

Current assessment practices and high teacher workloads seem to have eroded time that physics teachers would otherwise use to prepare interesting lessons and to engage in professional development. Given the data on professional development undertaken by physics teachers,

physics, teachers may not have had much professional development about how to make the content of their lessons interesting and related to students' interests.

The teachers also expressed concerns about some of the achievement standards being taught in the schools. Particular reference was made to Modern Physics, which the teachers asserted requires teaching physics content largely dated pre 1908. These physics teachers did not see anything modern about this standard and felt that this content was irrelevant now to their students. Bernard and Vicky, two of the case study teachers, wondered why the NCEA assessment required teachers to teach Modern Physics rather than about digital technologies – semiconductors, transistors and diodes (or nanotechnological research). It is reasonable to mention that most of the students leave high school without any knowledge about semiconductors and/or how transistors work. Semiconductors are the foundation of modern electronics and devices containing semiconductors can be used for amplification, switching, and energy conversion (Cutnell & Johnson, 2007; Gibbs, 2003). It is an undeniable fact that students are surrounded by devices that operate with semiconductors, yet the opportunity to study this more relevant content passes them by.

Findings from the study also suggest that junior science does not adequately prepare students for senior physics classes. Both the teachers and students indicated that students are rarely exposed to quality physics teaching at the lower school levels. There is reason to believe that some students (especially those in Years 9, 10 and 11) are taught physics, by teachers who have specialised in chemistry or biology and therefore do not have an extensive background in Physics. These teachers often do not have sufficient physics content knowledge, which may disadvantage their students. Such students are less likely to be motivated to pursue further physics study.

There seems to be more biology teachers teaching junior science in New Zealand schools and the attitude of these teachers to physics may be a negative determinant of student interest in the subject. If these teachers hold negative opinions of physics, do not understand it or do not have a

passion for teaching it, then students may quickly conclude that the subject is irrelevant, too difficult to master or boring. This has probably contributed to lower numbers of students choosing physics and possibly lower achievement as well. It is reasonable to surmise that the lack of subject specialists has created this situation over a number of years. The numbers of students taking a subject at senior levels determine the number of teaching specialists required at those levels. So this situation is likely to remain until there is more demand for physics at senior high school level.

The teachers' survey data (Table 19 and Table 20) showed that physics teachers felt they were not adequately supported and/or rewarded by the government and the general public. More specifically, the teachers claimed that teaching in general was not accorded a high professional status and teachers were generally not being treated as professionals and equivalent to their counterparts in other professions such as medicine and engineering. The teachers' interview data also corroborated the survey data and revealed that the public perception of teaching was generally negative and that the teaching profession was under-valued. In addition, the pay scale did not always reflect the amount of work required.

Other important factors mentioned by the teachers that limited quality physics teaching and learning included students' misconceptions about physics, the connection between mathematics and physics, and lack of technical support. These findings are in line with other international studies (see for example Crowe, 2007; Liu & MacIsaac, 2005; Vosniadou, 2007; Wiser & Amin, 2001). The teachers in this study perceived the connection between mathematics and physics as a challenge to most students in their classes. The classroom observations and post observation interview data however, showed that teachers of physics were not doing much to address this perceived problem. Philip, for instance, maintained that mathematics is a prerequisite which could not be developed while teaching physics. This is contrary to Vosniadou's (2007) suggestion that physics instruction must address the basic problems (gaps in skills and understanding) of students identified by the teacher.

The findings from this study also match with Angell et al. (2004) who found that physics teachers “complained about students’ poor mathematical skills” (p. 701), thereby making students not appreciating the beauty of the subject. Students in Angell et al.’s study however, did not see mathematics to be a problem and rather expressed that physics required understanding (including the mathematics) but the dominated chalk and talk approaches to classroom instructions did not support it. Although the students in Angell et al.’s (2004) study perceived physics as interesting and related to everyday phenomena, they also perceived the subject as difficult/demanding, formalistic in nature and more mathematical and demanding a variety of teaching approaches to make physics more interesting to learn. Based on the findings from their study, Angell et al. concluded that “secondary physics education preparing students for tomorrow’s society should be characterized by variety, both within and among courses, integration of mathematics in the physics courses, and more student-centred instruction” (p. 703). Findings from the students’ interviews suggested that teachers of physics must do more on the mathematical aspects of the subject to enhance students’ understanding, interest and capabilities.

The findings also support similar observations made by Mulhall and Gunstone (2012). Through semi-structured interviews and observations, the authors found that physics was seen by the traditional teachers as hard because it is mathematical and abstract, and many learners do not have the necessary skills to learn it. The conceptual teachers on the other hand believed that learning involves cognitive activity by the learner, and that individuals construct their own understanding in terms of their personal frameworks. They saw discussion as being important for learners as it helps tease out and develop understandings of physics ideas (Mulhall & Gunstone, 2012).

It is a well-known fact that physics cannot exist without mathematics and it is the mathematical nature of physics that makes it unique from the other science disciplines (Mulhall & Gunstone, 2012). It seems that this poses a problem to physics teachers who do not have a strong background in mathematics. Students who are the recipients of what is being taught by the teachers

tend to suffer if teachers decline to teach the mathematics aspect of physics and assume that students already know and have the computational skills required. Mulhall and Gunstone (2012) reported that, to the student who did not understand, the traditional teachers response was to tell the student to work harder whereas the conceptual teacher “acted as a diagnostician” (p. 445) and designed activities that responded to the student’s difficulties. Bernard and Vicky can be likened to the conceptual teachers who were committed to making physics more relevant and interesting to learn through the use of teaching approaches that focused on developing students’ understanding.

Perceived Ways for Improving Physics Teaching and the Numbers Involved

The findings from the teachers’ survey and the case studies revealed a number of ways and/or changes that might help to improve the quality of the teaching of physics and the numbers involved. One of the significant changes that is important to the teachers is reduction in the curriculum content and assessment requirements. As mentioned previously, the findings revealed that the current teaching load, assessment practices and paper work are a major hindrance which seems to have taken up the time that could have been used to prepare interesting lessons. The emphasis placed on high stakes assessment for Year 12 and 13 students should be looked into so that teachers can spend more time teaching and helping students to learn. Also, the quality of physics teaching and the numbers can be improved if more qualified teachers are put in front of the students.

Recruitment of more qualified teachers means that more physics graduates and postgraduate physicists (especially those who are capable and enthusiastic about physics) should be encouraged and supported into the teaching profession. The findings about the number of students in this study who want to become teachers suggest that the flow of people moving into physics teaching as a career needs to be addressed urgently. Perhaps, the current model of training and recruiting more

qualified physics teachers (Etkina, 2010; Hodapp et al., 2009) which is now being used in some parts of the United States can be considered.

Similarly, the findings from the study reveal a strong demand for an improved physics teaching and mathematics tuition especially at the junior levels where students develop most of their misconceptions about physics. Findings from the study reveal a lot of physics teachers at the junior levels have no physics in their background or they may have included only a small amount of physics in their qualification. These teachers may not have the kind of knowledge to handle difficult physics situations in the classroom. They would need more content preparation so that they can make the subject more relevant and interesting to the students. The standard of physics teaching will continue to fall and the numbers will continue to drop if the necessary steps are not taken to recruit more qualified teachers. In Australia, one of the proposals to reverse the “worrying decline” in the number of students taking physics is for physics teachers to be required to study the subject at university level (Pockley, 2013). New Zealand could consider such a proposal, given that ITE programmes here are currently exploring shifting their entry qualification to Masters level.

If physics teachers are to maintain a commitment to their subject and better approaches to teaching and learning opportunities to their students then their identity and true value must be recognised and respected. Findings from the study suggest that the teachers would also be motivated by improved wages and incentives that are at least equivalent to that earned in competing and potentially appealing alternative professions. There might also be ways to incentivise prospective physics teachers into the profession such as providing university scholarships that bond them to teaching.

CHAPTER 7

SUMMARY, CONCLUSION AND RECOMMENDATIONS

Summary

Overview of Research Problem and Methodology

In this concluding chapter, the most important findings are highlighted, and some recommendations are offered to improve upon the teaching and learning of high school physics. The study focussed on high school physics education in New Zealand. It sought insight into policies and practices that might promote excellence in physics teaching and also improve the number of students (and possibly teachers) involved. It also investigated how approaches to teaching high school physics in New Zealand influenced students' perceptions of physics and their consequent desire to continue with physics.

The study sought insight into the course structure, course components and programme requirements for physics education in New Zealand. More importantly, it investigated whether tertiary study adequately prepared and allowed pre-service teachers to become effective in their job. Initial teacher educators assume a daunting responsibility when preparing students to become effective and pedagogically competent classroom practitioners. Initial teacher education programmes must enable pre-service teachers to acquire professional knowledge from multiple dimensions, including subject matter and content knowledge, general and pedagogical content knowledge and knowledge of learners and learning (Darling-Hammond & Baratz-Snowden, 2005). My study explored New Zealand physics teachers' perceptions of their ITE experience, specifically, how well it prepared them for classroom practice and to become effective physics teachers.

The study followed a mixed method design and used both survey and case study techniques to examine the views of high school physics teachers, Year 12 and 13 physics students and those involved in physics teacher education. There were two stages to the approach. The first stage involved an online survey of high school physics teachers throughout New Zealand and physics students at some selected high schools in Christchurch. The second stage was meant to provide ‘on the spot’ evidence to substantiate the findings from the first stage. Thus, the second stage involved classroom observations, individual teacher interviews, and students’ focus group interviews. A case study approach was adopted for this purpose to provide an in-depth richness and understanding of the topic under investigation. At this stage, information about physics education programmes was also gathered from those involved in physics teacher education.

Key Findings

In this section, both the new knowledge generated from the study and the key findings that contribute to the existing knowledge are highlighted.

1. One significant finding of the study was that there is a lack of alignment between the aspirations of the *NZC*, which promotes inquiry and solving problems, and how physics is actually being taught in New Zealand.
2. Challenges associated with the quality teaching and learning of high school physics were identified by the participants as:
 - a) assessment and NCEA requirements;
 - b) the alignment of NCEA achievement standards with the curriculum;
 - c) limited time to prepare interesting lessons;
 - d) inadequate quality tuition of physics through the lower school levels;
 - e) lack of subject specialists;
 - f) lack of teacher support and development; and
 - g) weak mathematics background of students.

3. Participants identified that the quality of physics teaching and the number of students involved could be improved through:
 - a) a reduction in curriculum content and assessment requirements;
 - b) recruitment of more qualified physics teachers;
 - c) provision of on-going professional learning on content knowledge;
 - d) improved physics and mathematics tuition for students at junior level; and
 - e) improved salaries and support for professional learning for teachers.
4. The survey data indicated that student-centred instructional approaches were not common in many physics classes and in most cases, teachers decided what happened in the classroom. Students ideas and suggestions played little role in the planning of teaching and learning processes.
5. Students had little opportunity to plan and implement their own designs for experiments. Most of the time students performed experiments by following instructions from the teacher. Students were generally dissatisfied with many of the teaching approaches and wanted more student-centred classroom instruction.
6. Physics teachers in this study only occasionally used ICT tools to enhance the teaching and learning of physics. The low use of ICT tools in physics teaching, revealed by the national survey, confirms that more traditional approaches are common in physics instruction.
7. More than a quarter of the respondents were physics teachers initially trained to teach in a different subject area (see Figure 6). The reason for their change in discipline was mainly due to a shortage of physics specialists or because they took the opportunity to take up positions available in physics teaching.
8. The majority of New Zealand physics teachers who participated in the study specialised in physics and therefore completed a traditional undergraduate physics course.

9. Despite the fact that the majority of the teachers completed a traditional undergraduate physics course, the physics teachers perceived themselves as not well-prepared in some content areas currently taught in the schools, in particular electronics, atomic and nuclear physics and modern physics (see Table 6).
10. The ITE programmes undertaken by the physics teachers in this study were primarily focused on developing pedagogical content knowledge and are not designed to cover subject matter content knowledge. The content knowledge physics teachers gain arises mainly from their participation and learning in their undergraduate non-education degree. They have to bridge gaps in their knowledge through whatever means they can, for example through personal reading and learning from colleagues during cluster meetings and conferences.
11. There was a direct relationship between physics teachers' conceptions about teaching and their teaching practices. The case study teacher participants carefully chose teaching approaches according to their conceptions about teaching.
12. The time allocated by schools for teachers to work with their students in class and other demands of the curriculum compelled some of the teachers to compromise their ideal and aspirational conceptions about teaching, leading to the formation of new conceptions about teaching. Refer to the example of Vicky who was convinced that "students learn by doing" but due to the demands of assessment and other time constraints, felt she had to "feed students with content knowledge".

Conclusion

The findings from the study lead to a number of conclusions about the teaching and learning of high school physics. First of all, the findings suggest that there is lack of student-centred instructional approaches. In their responses to the survey and the focus group interviews, students indicated that hands-on activities with real world application of concepts learnt rarely happened in senior physics classes. Many students also reported that their physics class was difficult and

often boring, and dominated by the teachers. It can be concluded that most of the students experienced a traditional approach to teaching rather than a more student-centred inquiry-based or problem-based one. The use of more traditional teaching approaches for teaching physics might have contributed to students thinking that physics is a difficult and boring subject and not something they want to participate in further. The use of traditional approaches, such as lectures with PowerPoint presentations, copying notes and working through exercises from textbooks/workbooks was prevalent in the lessons observed.

Teachers' survey responses, which were triangulated with classroom observations and interviews, indicated that physics teaching in New Zealand is very assessment focused. The teachers mentioned that the New Zealand assessment system for physics values recall of content knowledge and therefore this is what teachers focus on. Students also expect that the content will be "covered" so they know what to learn. The emphasis on high stakes assessment has made teachers concentrate more on the content directly related to assessment tasks for senior students rather than on preparing inquiry-based lessons that would facilitate conceptual change and stimulate students' interest in the subject. The teachers considered that limited time to work with students and the assessment demands, with its heavy workload, had worsened the problem of finding time to prepare interesting physics lessons.

Although the *NZC* allows teachers freedom to design their own lessons and it promotes inquiry and problem-based approaches, there is a lack of alignment between the aspirations of the curriculum and how physics is actually being taught. The participant teachers were frustrated by the fact that meeting the aspirations of *NZC* had taken second place to satisfying the demands of the assessment system. Vicky was convinced that as long as students have to be assessed by NCEA examinations, the aspirations of the *NZC* were not going to be achieved, as she commented below:

I am being forced to teach what NCEA wanted us to assess...at the end of the day, I am being judged by how well they (students) do in tests, students are

getting judged by how well they do in the tests and this, consequently takes them away from learning because preparing for assessments is different from learning (Vicky).

The assessment demands have compelled some of the participant teachers to compromise their long-held conceptions about teaching. For example, Vicky wished to allow students to engage in hands-on activities and Nick (a proponent of peer instruction) wanted to reflect minds on approaches to teaching and learning and run discussion groups but both found there was limited time available for these things. The teachers struggle to have the students answer the assessments and there is little or no time for extra exploration of the subject.

The contribution of ICT to the physics teaching and learning environment is potentially significant since ICT can impact positively on the learning practices, learning outcomes and students' attitudes toward physics studies (Chandra & Watters, 2012; Wieman & Perkins, 2005; Wieman et al., 2008). Findings from the present study show that teachers thought they could use ICT more in physics teaching. As shown in the survey data (see Table 14 and Figure 14), most teachers do not make use of ICT tools to contribute to physics teaching and learning environments. There are huge numbers of teaching resources available online (for example PhET, Applets, RealTime physics) which teachers can employ to facilitate the teaching and learning of physics concepts. These resources can make a difference to practices, learning outcomes, and encourage greater participation of students in physics studies.

Findings from the study also provide insight about physics teachers' preparation and indicate that the physics education programmes for would-be physics teachers generally do not cover content knowledge for the subject. That is, the physics teacher education programmes are primarily about PCK. It is evident from this study that the physics teachers considered themselves not adequately qualified/prepared to teach some of the content areas in the curriculum. In part, this

may be due to the non-education degree which provided the teachers with most of their physics content knowledge.

The teachers' perceived need for professional learning to deepen their subject matter content knowledge suggests that the content knowledge provided by the non-education degree was inadequate and did not address the needs of the teachers. As discussed in the previous chapter, ITE programmes need to be aware of this and respond appropriately (OECD, 2014). Among other things, Etkina (2010, pp. 21-22) recommends that physics teacher preparation should enable pre-service teachers to learn physics through the pedagogy that pre-service teachers need to use when they become teachers, learn how the processes of scientific inquiry works and how to use this inquiry in a high school classroom for specific physics topics, and learn what students bring into a physics classroom and where their strengths and weaknesses are.

It can be inferred from the findings that the quality of physics teaching has been linked to teacher quality and subject expertise (see for example Table 21). Data for the study have shown that, more than a quarter of the teachers switched to physics from another discipline when there was a shortage of physics specialists (refer to Figure 6 and Figure 8). The lack of qualified physics teachers persists and the problem of recruiting qualified physics teachers has negatively impacted on physics teaching at the junior level (see Table 20 and Table 21). There is reason to conclude that some students may not meet a physics teacher until Year 12, by which time they may have already formed important misconceptions about key physics concepts and made choices about future study or a career. Greater participation in physics studies can be achieved if the subject is made interesting to students at the junior level. There is no doubt that the beginnings of the problem of students' difficulty with physics happens at the junior level where students are seldom exposed to quality physics teaching.

This study has discussed in some detail how students perceive physics studies and why they (students) would or would not wish to become physics teachers. It is logical that students will tend

to be less interested in the subject if the strategies suggested for enhancing greater participation are not adopted and implemented. Thus physics teachers as well as science educators in the physics community should seek to work for the students' interests and respond to the students' concerns in the interventions/strategies they develop. After all, the *New Zealand Curriculum* (Ministry of Education, 2007) demands that teachers address the interests and personal learning needs of their students.

Given that most of the physics students in this study do not want to become physics teachers (but rather want to be in highly paid jobs like Engineering), there is clearly not a functioning "pipeline" for supplying physics teachers for the future. Until these concerns are addressed, the standard of physics teaching seem unlikely to improve and the decline in interest in the subject will continue (Buabeng, Conner, & Winter, 2015).

Implications

The study has reported on important variables related to high school physics teaching and learning in New Zealand. In part, the study has determined high school physics teachers' perceptions of the adequacy of their preparation to teach their subject. More than a quarter of the respondents were physics teachers with an initial degree not specialising in physics. Their change in discipline was due to a shortage of physics specialists or because an opportunity arose to teach physics. Teachers who completed their initial teacher education between 1965 and 1987 reported a lower level of knowledge of content and curriculum goals than students who had graduated more recently. In addition, the teachers in the survey reported feeling not well-prepared to teach content areas such as electronics, modern physics and nuclear physics. Teachers prepared outside of New Zealand were less prepared than those that were prepared in New Zealand. The overall implication is that teachers need more content preparation or help to find ways to develop their content competencies for themselves. As indicated by the respondents, continuing professional development and learning must also be more responsive to the needs of teachers from other science

disciplines choosing or being required to teach physics because of the shortage of physics teachers worldwide.

The findings that most physics teachers in this study rarely used ICT tools for physics teaching was a concern and should be an area for future professional development for teachers. Professional learning can make an important difference in the experiences and capacities that these teachers have, and hence initial teacher education providers within Faculties of Education as well as in-service events provided by the Ministry of Education could help physics teachers to deepen their content subject matter knowledge and pedagogical knowledge whilst simultaneously encouraging them and upskilling them in the use of ICT tools. There is an obligation for these institutions to implement practices to enhance the quality of teaching and learning of physics in schools.

Findings from this study also suggest that in the past the traditional model for physics teacher education has not always provided the preparation that is now needed to effectively teach physics. Because of the age of the teachers and when they did their initial teacher training, student-centred pedagogies and the use of ICT, critical thinking, inquiry etc. were not necessarily emphasised as much as now. That is, their teacher education was appropriate for that time, but is no longer adequate and they need on-going professional learning opportunities. The challenge for teacher educators is to ensure that today's teacher preparation programmes are responsive to the needs of physics graduates who aspire to be effective teachers. As Conner and Sliwka (2014) have suggested, as ITE programmes are revised and renewed, they need to build in processes for student teachers to self-identify what content areas they need to work on through diagnostic testing, and to accommodate the different needs that students have due to their diverse backgrounds and different levels of content and pedagogical knowledge. This would go some way to addressing the diverse backgrounds amongst candidates entering ITE institutions. Given that ITE programmes in New Zealand are currently exploring shifting to Masters level, it is timely to reconsider what

subject matter content knowledge and pedagogical knowledge is included in physics teacher preparation.

Physics teachers could be encouraged and/or assisted to attend cluster meetings in their area where they could develop local peer networks to share what they do and to decrease isolation. It is likely that some of the teachers who were part of the national survey are the only physics teacher in their schools, as in the case of Vicky. Therefore, a social media network might also be useful for teachers around New Zealand to discuss physics problems related to innovative pedagogy and sharing of ideas for teaching content knowledge.

Given that more than a quarter of the respondents were 51 years and over, these teachers will soon retire from teaching and they will need replacement, which may present a challenge to many schools. Philip has already retired from teaching and Bernard will soon follow suit. As it is unlikely that the number of physics teachers will soon increase, some schools will continue experiencing difficulty recruiting suitably qualified staff to teach physics. The declining student interest at both high school and university levels will continue to result in fewer teachers coming through which will adversely affect the teaching of physics.

Some possible ways to increase the number of physics teachers might include partnerships between stakeholders and businesses to provide scholarships for people who have specialised in physics to become teachers and for people with physics related careers to be diverted into teaching through financial incentives. The majority of the teachers in the study became physics teachers through financial incentives and personal interest (Figure 7) and also, more than a quarter of the teachers had switched to physics from another science discipline (Figure 6). These findings suggest some possibilities for how more teachers might be attracted to the profession. Part-time pathways for initial teacher education might also assist potential physics teachers to participate in ITE programmes.

Recommendations

From the findings of this study the following recommendations are offered:

1. The current assessment practices and high teacher workloads should be reviewed so that teachers can spend more time ‘teaching’ and helping students to learn physics. The subject could be made less demanding by reducing the number of topics/concepts required to be covered in the senior levels.
2. Education providers and other stakeholders of education should make a concerted effort to support and educate more physics graduates for working in the classroom. Part-time pathways could be considered for this purpose.
3. Professional learning programmes should be implemented on a regular basis to support teachers in deepening both their content and pedagogical content knowledge to make learning for their students more interesting and relevant.
4. The current initial physics teacher education system where teacher education providers have the freedom to design their own courses and programmes could be reviewed. There is no national teacher education curriculum in New Zealand as occurs in some countries. Therefore, it is likely that different teacher education providers have prepared current teachers differently. This occurs for all other disciplines as well and a national teacher education curriculum might be helpful.
5. Teacher educators should develop a closer association or work more closely with university physics departments so that they can include more interactive approaches to learning. Since teachers’ understanding of physics is mainly gained through learning within undergraduate physics courses, it is important that lecturers teaching these courses model effective approaches for teaching and learning.
6. Physics teachers have the potential to make a significant impact on student numbers participating in further physics studies. How they engage students by connecting with

student interests and how they share their passion for curiosity about physics can make a difference to students (see for example Figure 12 and Figure 13). The teachers therefore have a responsibility to reflect minds on approaches to teaching and learning in which students can learn and appreciate the beauty of the physics.

7. It is recommended that, as far as possible, physics teachers integrate mathematics within the physics course to enhance students' understanding and interest in the subject. Both the survey data (see Table 18) and case study participant teachers complained about students' poor mathematical skills and that the connection between mathematics and physics was a major hindrance. Students in the focus group also mentioned that rather than assuming they (the students) already know and be rushed through the mathematics, teachers should take time and teach the mathematics in context.

Limitations of the Study

The integration of quantitative and qualitative data from the different research methods afforded advantages to the study. The two methodologies provided different levels of detail which complemented each approach to answer the research questions. For example, the qualitative approach enabled me to gain more detailed and rich data in the form of comprehensive written descriptions and visual evidence that were absent from the survey data. However, since the two methodologies are based on different assumptions, each one has limitations. The researcher's personal biases and idiosyncrasies potentially could have been a major limitation of the qualitative approach (Cohen et al., 2007; Fraenkel et al., 2012; Gray, 2009; Sarantakos, 2005) and possible effects to the findings was resolved through "member checking" (Fraenkel et al., p. 458). Member checking was employed to verify the accuracy of the information from participant teachers before any part was reported in this study.

In spite of the many advantages online surveys offer over traditional surveys, for example, the ability to reach individuals who would be difficult or impossible to reach, cost effectiveness and

time saving for researchers (Fraenkel et al., 2012; Sarantakos, 2005), online surveys come with their own limitations. In this study, the limitations were whether the teachers were able to accurately assess themselves in terms of their teaching and whether they accurately reported that. There was no guarantee that the respondents in the survey accurately assessed themselves regarding the teaching and accurately reported it. Nonetheless, multiple questions were used to cross-check their responses. That is, reliability coefficients were computed, and the alpha values obtained (refer to the section on validity and reliability – chapter 3) indicated that the responses were reliable and could be used for research purposes.

The focus on four case study high school teachers in Christchurch and three teacher educators placed a limitation on the study. This was due to the limited time at the researcher's disposal and the willingness of schools to participate in the study. Also, the purposive sampling technique used to select case study institutions decreased the generalizability of the findings. It is possible that other teachers from different schools may have offered important information which would have been relevant to the study. The findings from the case studies will therefore not be generalizable to all schools within New Zealand. However, the findings serve as indicators of what may be happening in other schools within the country. This limitation is somewhat addressed by having the national survey data which provided potentially more generalizable findings.

The teachers' accounts of what they did were triangulated through classroom observations. However, the observations themselves could lead to the "Hawthorne effect". Although the respondents consented before observations were carried out, it is natural that when people are aware that they are being observed, they tend to perform better and this can affect the findings of the study. However, since respondents were observed teaching multiple times and any differences between the teacher's and researcher's scores were reconciled, it is possible that true behaviours were exhibited. Again, the opinions of physics students in the study about their teacher's teaching, were used to establish trustworthiness of the teachers' accounts. However, the students' interviews

may affect the findings of the study since students' responses may be influenced by fear, hatred, love and other emotional concerns about their teachers. To mitigate against this possible effect, all students were assured of the confidentiality of the data gathered and the students' names and identifying details were changed to pseudonyms.

Suggestions for Further Research

Based on the findings from the study, the following suggestions are provided for further studies:

1. The teachers who participated in this study commented that the biggest difficulty to enhancing quality physics teaching and learning were the assessment and NCEA requirements. This raises the issue of whether the current physics teaching and learning practices is meaningful and beneficial to learners which the *NZC* aspires to promote. Further studies will be required to look at the impact of assessment on teachers' practices and students' learning.
2. There is a perception among the teachers that the physics curriculum consists of essentially pre 1905/1908 content which is "totally irrelevant now". Further studies could assess the relevance of the physics content currently taught (and the content that is not taught) for future review and planning for a more relevant 21st Century physics education.

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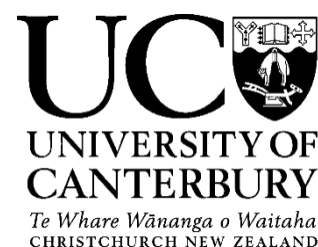
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Appendix A: Ethics Approval Letter



HUMAN ETHICS COMMITTEE

Secretary, Lynda Griffioen
Email: human-ethics@canterbury.ac.nz

Ref: 2013/36/ERHEC

5 July 2013

Isaac Buabeng
School of Educational Studies and Human Development
UNIVERSITY OF CANTERBURY

Dear Isaac

Thank you for providing the revised documents in support of your application to the Educational Research Human Ethics Committee. I am very pleased to inform you that your research proposal "Teaching and learning of Physics in New Zealand secondary schools" has been granted ethical approval.

Please note that this approval is subject to the incorporation of the amendments you have provided in your email of 5 July 2013.

Should circumstances relevant to this current application change you are required to reapply for ethical approval.

If you have any questions regarding this approval, please let me know.

We wish you well for your research.

Yours sincerely

A handwritten signature in dark ink, appearing to read 'Nicola Surtees', written in a cursive style.

Nicola Surtees

Chair

Educational Research Human Ethics Committee

"Please note that Ethical Approval and/or Clearance relates only to the ethical elements of the relationship between the researcher, research participants and other stakeholders. The granting of approval or clearance by the Ethical Clearance Committee should not be interpreted as comment on the methodology, legality, value or any other matters relating to this research."

E S

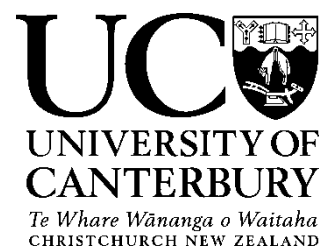
Appendix B: Information and Consent Forms

College of Education

School of Educational Studies and Leadership

Tel: +64 3 364 2987

Ref: 2013/36/ERHEC



Teaching and Learning of Physics in New Zealand Secondary Schools

Information Sheet for Case Study Physics Teachers

I am a PhD student at the College of Education, University of Canterbury, Christchurch. I am conducting a study into the teaching and learning of physics in high schools. The study follows a mixed method design and uses both survey and case study techniques to examine the views of a variety of stakeholders, including exemplary physics teachers and those involved in physics teacher education. It is hoped that the findings from the study may promote excellence in physics teaching practices and also improve the numbers of students studying physics at high school level and beyond.

Your experience and ideas would make an important contribution to this research. I therefore invite you to participate in the study. If you agree to be part of this project, I will interview you about your experiences as a physics teacher. The interview, which will be audio recorded and take about 20-30 minutes, will focus on the following: the training of high school physics teachers; your perceptions about classroom interactions and how they are related to effective learning; professional learning and development services for physics teachers; factors constraining the quality teaching and learning of physics; and ways to improve teaching and learning of high school physics. I would also like to make 3-4 fifty (50) minute classroom observations of you teaching physics and audio record these lessons. During each lesson you may request that the recording be stopped temporarily or permanently at any time. I would also like to look at your lesson plans for these observed lessons.

Your participation in this project is voluntary and you may withdraw from the study at any time. If you choose to withdraw, I will remove any of the information relating to you from the project, including any final publication, provided that this remains practically achievable. All participants are assured confidentiality of the data gathered. Names and identifying details in any verbal, written or published reports will be changed into pseudonyms. Any published or reported results from this study will not identify any participant and his/her institution. A copy of the interview transcript will be made available to participants to check for accuracy. Also, a copy of the report on the findings of the study will be made available to participants. Audio-tape and/or observation notes will be kept in a locked cupboard and will only be accessible to me and my supervisors. These materials will be kept for 5 years and then destroyed.

If you would like more information or have any questions about the research, you can contact me or my supervisors, Assoc. Prof. Lindsey Conner (lindsey.conner@canterbury.ac.nz) and Dr. Dave Winter (david.winter@canterbury.ac.nz). If you have any concerns or complaints about this research, please contact *The Chair, Educational Research Human Ethics Committee, University of Canterbury, Private Bag 4800, Christchurch (human-ethics@canterbury.ac.nz). Office Phone: (03) 364 2987 ext. 45588.*

If you are happy and willing to participate in this project please sign the consent form and return it to me in the envelope provided. Please retain this information sheet. Thank you for considering this request.

ISAAC BUABENG (isaac.buabeng@pg.canterbury.ac.nz) Office Phone: (03) 364 2987 ext. 43225

Teaching and Learning of Physics in New Zealand Secondary Schools

Case Study Physics Teachers' Consent Form

I understand the aims and purposes of the research study being undertaken by *ISAAC BUABENG*.

- The study has been explained to me and I understand the information that was given to me on the information sheet.
- I am aware that my participation in this project is voluntary and I have had all questions answered to my satisfaction.
- I understand that my involvement will include an individual interview and observations of me during teaching.
- I understand that interviews and observations will be audio recorded and I can ask for the recordings to be stopped at any time temporarily or permanently.
- I understand that I will be provided with a copy of the interview transcript to check for accuracy.
- I understand that I can withdraw from the study at any time, and that I do not have to give any reason for withdrawing.
- I understand that all information will be treated confidentially and will be used for research purposes only. I understand that data collected for the study will be kept in locked and secure facilities and/or in password protected electronic form and will be destroyed after five years.
- I understand that within these restrictions, the findings may be submitted for publication to national or international journals or presented at educational conferences.
- I understand that a copy of the research results will be made available to me upon request using the email address I have provided below.
- I understand that the study will be carried out as described in the information statement and consent form, copies of which I have retained.
- I have read the information sheet and consent form. I agree to participate in the study.

Name: _____

Signature: _____

Date: _____

Teaching and Learning of Physics in New Zealand Secondary Schools

Information Sheet for Physics Teachers Online Survey

Please read the following before completing the survey

I am a PhD student at the College of Education, University of Canterbury, Christchurch. I am conducting a study on teaching and learning of physics in high schools. The study follows a mixed method design and uses both survey and case study techniques to examine the views of a variety of stakeholders, including exemplary physics teachers and those involved in physics teacher education. It is hoped that the findings from the study may promote excellence in physics teaching practices and also improve the numbers of students studying physics at high school level and beyond.

Your experience and ideas would make an important contribution to this research. The information provided in this survey will contribute to a better understanding of teachers' initial education, professional development and pedagogical content knowledge and strategies physics teachers use for teaching physics. The information provided is likely to be useful in discussions about professional learning and development services for physics teachers, for both those who are physics majors and those who teach physics but who do not have a physics degree.

If you agree to take part in this study, you will be asked to complete a survey which will take about 20-25 minutes. All participants are assured of anonymity and confidentiality of the data gathered. Names and identifying details in any form will be changed into pseudonyms. Data gathered will be kept in locked and secure facilities and/or in password protected electronic form and be destroyed after five years. Please note that your participation is completely voluntary and you can therefore withdraw from the study at any time. If you withdraw, I will remove any information relating to you including any final publication, provided that this remains practically achievable.

If you would like more information or have any questions about the research, you can contact me or my supervisors, Assoc. Prof. Lindsey Conner (lindsey.conner@canterbury.ac.nz) and Dr. Dave Winter (david.winter@canterbury.ac.nz). If you have any concerns or complaints about this research, please contact *The Chair, Educational Research Human Ethics Committee, University of Canterbury, Private Bag 4800, Christchurch* (human-ethics@canterbury.ac.nz). Office Phone: (03) 364 2987 ext. 45588

By completing this survey, it is understood that you have consented to participate in the study, and that you consent to publication of the results of the study with the understanding that anonymity will be guaranteed. Thank you for considering this request.

ISAAC BUABENG (isaac.buabeng@pg.canterbury.ac.nz) Office Phone: (03) 364 2987 ext. 43225

College of Education

School of Educational Studies and Leadership

Tel: +64 3 364 2987

Ref: 2013/36/ERHEC



Teaching and Learning of Physics in New Zealand Secondary Schools

Information Sheet for Students

I am a PhD student at the College of Education, University of Canterbury, Christchurch. I am conducting a research project into the teaching and learning of physics in high schools. The study examines the policies and practices that support physics teachers and students to be successful and the perceptions of teachers and students about changes that might promote excellence in physics teaching and also improve the numbers of students studying physics at high school level and beyond.

Your experience and ideas as a student will make an important contribution to this research. I am therefore inviting you to participate in the study. If you decide to take part in the study, I will interview you about the teaching and learning of physics. The interview will be in groups of 3-4 students and you will be asked to treat all shared information as confidential. In addition, you will be asked to complete one questionnaire related to the study. The interview will be audio recorded and take about 20-30 minutes. I would also like to look at some of your previous physics and science assessment results for the last two years.

You may request the recordings to be stopped temporarily or permanently at any time. Your participation is voluntary and you may withdraw from the study at any time without penalty. All students are assured of confidentiality of the data gathered. Names and identifying details in any verbal, written or published reports will be changed into pseudonyms. Any published or reported results from this study will not identify any students and his/her institution. A copy of the interview transcript will be made available to participants to check for accuracy. Audio-tapes and notes will be kept in a locked cupboard and will only be accessible to me and my supervisors. Also, a copy of the report on the findings of the study will be made available to participants. These materials will be kept for 5 years and then destroyed.

If you would like more information or have any questions about the research, you can contact me or my supervisors, Assoc. Prof. Lindsey Conner (lindsey.conner@canterbury.ac.nz) and Dr. Dave Winter (david.winter@canterbury.ac.nz). If you have any concerns or complaints about this research, please contact *The Chair, Educational Research Human Ethics Committee, University of Canterbury, Private Bag 4800, Christchurch* (human-ethics@canterbury.ac.nz). Office Phone: (03) 364 2987 ext. 45588.

If you are happy and willing to participate, please sign the consent form and return it to me in the envelope provided. Please retain this information sheet. Thank you for considering my request to participate in this research project.

ISAAC BUABENG (isaac.buabeng@pg.canterbury.ac.nz) Office Phone: (03) 364 2987 ext. 43225

College of Education

School of Educational Studies and Leadership

Tel: +64 3 364 2987

Ref: 2013/36/ERHEC



Teaching and Learning of Physics in New Zealand Secondary Schools

Students' Consent Form

I understand the aims and purposes of the research study being undertaken by *ISAAC BUABENG*.

- The study has been explained to me and I understand the information that was given to me on the information sheet.
- I am aware that participation in this project is voluntary and I have had all questions answered to my satisfaction.
- I understand that my involvement will include a recorded interview and the completion of a written questionnaire.
- I understand that interviews will be audio recorded and I can ask for the recordings to be stopped at any time, either temporarily or permanently.
- I understand that, in the group interviews, students will treat what is shared as confidential.
- I understand that I can withdraw from the study at any time without penalty.
- I understand that I will be provided with a copy of the interview transcript to check for accuracy.
- I understand that all information will be treated confidentially and will be used for research purposes only. I understand that data collected for the study will be kept in locked and secure facilities and/or in password protected electronic form and will be destroyed after five years.
- I understand that within these restrictions, the findings may be submitted for publication to national or international journals or presented at educational conferences.
- I understand that a copy of the research results will be made available to me upon request using the email address I have provided below.
- I understand that the study will be carried out as described in the information statement and consent form, copies of which I have retained.
- I have read the information sheet and consent form. I agree to participate in the study.

Name of student: _____

Signature: _____

Date: _____

Ref: 2013/36/ERHEC

Teaching and Learning of Physics in New Zealand Secondary Schools

Information Sheet for Parents/Guardians

I am a PhD student at the College of Education, University of Canterbury, Christchurch. I am conducting a research project into the teaching and learning of physics in high schools. The study examines the policies and practices that support physics teachers and students to be successful and the perceptions of teachers and students about changes that might promote excellence in physics teaching and also improve the numbers of students studying physics at high school level and beyond.

Your child's experience and ideas as a student will make an important contribution to this research. I am therefore inviting your child to participate in the study. I will interview your child about teaching and learning of physics. The interview will be in groups of 3 – 4 students. The interview will be audio recorded and take about 20-30 minutes. Your child may request the recordings to be stopped temporarily or permanently at any time. In addition, your child will be asked to complete one questionnaire related to the study. I would also like to look at some of your child's previous physics and science assessment results for the last two years.

Your child's participation is voluntary and he/she may withdraw from the study at any time without penalty. All students are assured confidentiality of the data gathered. Names and identifying details in any verbal, written or published reports will be changed into pseudonyms. Any published or reported results from this study will not identify any students and his/her institution. A copy of the interview transcript will be made available to participants to check for accuracy. Also, a copy of the report on the findings of the study will be made available to participants. Audio-tapes and notes will be kept in a locked cupboard and will only be accessible to me and my supervisors. These materials will be kept for 5 years and then destroyed.

If you would like more information or have any questions about the research, you can contact me or my supervisors, Assoc. Prof. Lindsey Conner (lindsey.conner@canterbury.ac.nz) and Dr. Dave Winter (david.winter@canterbury.ac.nz). If you have any concerns or complaints about this research, please contact *The Chair, Educational Research Human Ethics Committee, University of Canterbury, Private Bag 4800, Christchurch* (human-ethics@canterbury.ac.nz). Office Phone: (03) 364 2987 ext. 45588.

If you are happy and willing to allow your child to participate please sign the consent form and return it to me in the envelope provided. Please retain this information sheet. Thank you for considering my request to allow your child to participate in this research project.

ISAAC BUABENG (isaac.buabeng@pg.canterbury.ac.nz) Office Phone: (03) 364 2987 ext. 43225

Teaching and Learning of Physics in New Zealand Secondary Schools

Parents/Guardians' Consent Form

I understand the aims and purposes of the research study being undertaken by *ISAAC BUABENG*.

- The study has been explained to me and I understand the information that was given to me on the information sheet.
- I am aware that participation in this project is voluntary and I have had all questions answered to my satisfaction.
- I understand that my child's involvement will include a recorded interview and the completion of a written questionnaire.
- I understand that interviews will be audio recorded and my child can ask for the recordings to be stopped at any time, either temporarily or permanently.
- I understand that my child can withdraw from the study at any time without penalty.
- I understand that participants will be provided with a copy of the interview transcript to check for accuracy.
- I understand that all information will be treated confidentially and will be used for research purposes only. I understand that data collected for the study will be kept in locked and secure facilities and/or in password protected electronic form and will be destroyed after five years.
- I understand that within these restrictions, the findings may be submitted for publication to national or international journals or presented at educational conferences.
- I understand that a copy of the research results will be made available to participants upon request using the email addresses I have provided below.
- I understand that the study will be carried out as described in the information statement and consent form, copies of which I have retained.
- I have read the information sheet and consent form. I agree to allow my child to participate in the study.

Name of parent/guardian: _____

Name of child: _____

Signature of parent/guardian: _____

Date: _____

College of Education
School of Educational Studies and Leadership
Tel: +64 3 364 2987

Ref: 2013/36/ERHEC



Teaching and Learning of Physics in New Zealand Secondary Schools

Information Sheet for Teacher Educators

I am a PhD student at the College of Education, University of Canterbury, Christchurch. I am conducting a study into the teaching and learning of physics in high schools. The study follows a mixed method design and uses both survey and case study techniques to examine the views of a variety of stakeholders, including exemplary physics teachers and those involved in physics teacher education. It is hoped that the findings from the study may promote excellence in physics teaching practices and also improve the numbers of students studying physics at high school level and beyond.

Your experience and ideas would make an important contribution to this research. I therefore, invite you to participate in this study. If you agree to be part of this project, I will interview you on your views about physics education in New Zealand. The interview, which will be audio recorded and take about 20-30 minutes, will focus on the following: the training of high school physics teachers; professional learning and development services for physics teachers; factors constraining the quality teaching and learning of physics; and ways to improve teaching and learning of high school physics. I will also take notes to supplement what will be recorded. You may request the recordings to be stopped temporarily or permanently at any time.

Your participation in this project is voluntary and you may withdraw from the study at any time. If you choose to withdraw, I will remove any of the information relating to you from the project, including any final publication, provided that this remains practically achievable. All participants are assured confidentiality of the data gathered. Names and identifying details in any verbal, written or published reports will be changed into pseudonyms. Any published or reported results from this study will not identify any participant and his/her institution. A copy of the interview transcript will be made available to participants to check for accuracy. Also, a copy of the report on the findings of the study will be made available to participants. Audio-tape and/or observation notes will be kept in a locked cupboard and will only be accessible to me and my supervisors. These materials will be kept for 5 years and then destroyed.

If you would like more information or have any questions about the research, you can contact me or my supervisors, Assoc. Prof. Lindsey Conner (lindsey.conner@canterbury.ac.nz) and Dr. Dave Winter (david.winter@canterbury.ac.nz). If you have any concerns or complaints about this research, please contact *The Chair, Educational Research Human Ethics Committee, University of Canterbury, Private Bag 4800, Christchurch* (human-ethics@canterbury.ac.nz). Office Phone: (03) 364 2987 ext. 45588.

If you are happy and willing to participate, please sign the consent form and return it to me in the envelope provided. Please retain this information sheet. Thank you for considering this request.

ISAAC BUABENG (isaac.buabeng@pg.canterbury.ac.nz) Office Phone: (03) 364 2987 ext. 43225

Teaching and Learning of Physics in New Zealand Secondary Schools

Teacher Educators' Consent Form

I understand the aims and purposes of the research study being undertaken by *ISAAC BUABENG*.

- The study has been explained to me and I understand the information that was given to me on the information sheet.
- I am aware that my participation in this project is voluntary and I have had all questions answered to my satisfaction.
- I understand that my involvement will include an individual interview which will be audio recorded, and that I can ask for the recording to be stopped at any time temporarily or permanently.
- I understand that I will be provided with a copy of the interview transcript to check for accuracy.
- I understand that I can withdraw from the study at any time, and that I do not have to give any reason for withdrawing.
- I understand that all information will be treated confidentially and will be used for research purposes only. I understand that data collected for the study will be kept in locked and secure facilities and/or in password protected electronic form and will be destroyed after five years.
- I understand that within these restrictions, the findings may be submitted for publication to national or international journals or presented at educational conferences.
- I understand that a copy of the research results will be made available to me upon request using the email address I have provided below.
- I understand that the study will be carried out as described in the information statement and consent form, copies of which I have retained.
- I have read the information sheet and consent form. I agree to participate in the study.

Name: _____

Signature: _____

Date: _____

Appendix C: Teachers' Survey Questionnaire

Dear Physics Teacher,

This questionnaire seeks your opinions and concerns about teaching and learning of physics in New Zealand schools and the education of physics teachers. The questionnaire is part of a PhD research project being completed at the University of Canterbury. Your responses will be treated confidentially and will be used for research purposes only. No person or school will be identified in any reports. Thank you for completing the questionnaire. Your cooperation is greatly appreciated.

Please make a tick in the box beside your selected response. Where there are no options given, write your response in the space below the question.

Section A: Bio data

1. Gender: Male ☐ Female ☐
2. Your age range (in years): 20 and below ☐
21 – 30 ☐
31 – 40 ☐
41 – 50 ☐
51 and above ☐
3. What is your highest level of educational attainment? (Tick that apply)
PhD ☐ M.Sc. ☐ M.Ed. ☐
1st Degree (BSc /BA) ☐
1st Degree (Ed.) ☐
Post Graduate Diploma ☐
Diploma ☐
Others (Specify).....
4. How many years of teaching experience have you had as a physics teacher?
< 1 year ☐
1-2 years ☐
3-5 years ☐
6-10 years ☐
11-15 years ☐
Above 15 years ☐
5. School type: Co-educational ☐
Girls only ☐
Boys only ☐
6. Which of these groups are you currently teaching? (Tick those apply)
Year 11 ☐ Year 12 ☐ Year 13 ☐
7. What is your school's decile ranking?
1-3 ☐ 4-7 ☐ 8-10 ☐
8. What is the authority of the school?
State ☐
Private ☐
Integrated ☐
9. What motivated you to become a science teacher with physics, in particular?
.....
.....
.....

Section B: Initial Teacher Training Program

10. Which country did you receive your initial teacher education (ITE)?

New Zealand ☐

Outside New Zealand ☐

(Specify):

Answer Q11 if your response to Q10 is New Zealand

11. What institution did you complete your initial teacher education (ITE)?

.....

12. What year did you complete your initial teacher education?

13. Was physics your primary/first-choice teaching subject?

Yes ☐ No ☐

Answer Q14 if your response to Q13 is Yes, go to Q15 if your response is No.

14. Have you completed the following college/university courses?

Courses	Yes	No
General methods of teaching		
Methods of teaching science/physics		
Assessment in science education		
Supervised student teaching in science/physics		
Algebra/trigonometry		
Calculus		
Advanced calculus		
Differential equations		
Probability and statistics		

15. Have you completed the following college/university courses? (**Answer this question if your response to Q13 was NO**)

Courses	Yes	No
General methods of teaching		
Methods of teaching science/physics		
Assessment in science education		
Supervised student teaching in science/physics		
Algebra/trigonometry		
Calculus		

Advanced calculus		
Differential equations		
Probability and statistics		
Introductory physics		
Electricity and magnetism		
Heat and thermodynamics		
Mechanics		
Modern or quantum physics		
Atomic and Nuclear physics		
Optics		
Waves		
Electronics		

16. To what extent did your initial teacher education (ITE) program prepare you to teach the following topics in physics? Please indicate by ticking [☐] the appropriate boxes.

Topics	Very well prepared	Adequately prepared	Not well prepared	Not sure
Mechanics				
Waves				
Electricity and Magnetism				
Electronics				
Atomic and nuclear physics				
Modern physics				
Investigations				
Applications				

17. How do the following statements correspond with your views/opinions about your initial teacher education? Please indicate by ticking [✓] the appropriate boxes.

My initial teacher education ...	Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree
Focused on the use of inquiry and problem-based learning approaches					
Incorporated the use of ICT into teaching and learning of physics					
Provided background on how children develop and learn					
Gave me with skills to observe, monitor, and assess children to gain accurate feedback about their learning and development					
Provided background about how children acquire and use language					
Provided background about how to observe an individual student with different tasks and other students to diagnose his/her need					
Provided knowledge of curriculum goals					
Enabled me to understand, interpret and implement the national and school curricula					
Enabled me to teach diverse student population					
Enabled me to create meaningful instruction that is motivating and engaging					

Section C: Professional development learning

18. How important do you think professional learning is in the following areas? Please indicate by ticking [✓] the appropriate boxes.

Learning areas	Very important	Important	Somewhat important	Not Sure	Not important
Learning how to use technology in physics instruction					
Learning how to use inquiry/investigation-oriented teaching strategies					
Understanding student thinking in physics					
Learning how to assess student learning in physics					
Deepening my own physics content knowledge					
Knowledge on the NZ curriculum					

19. Which of the professional learning have you undertaken in the past 5 years? Please indicate by ticking [✓] the appropriate boxes.

Learning areas	Yes	No
Learning how to use technology in physics instruction		
Learning how to use inquiry/investigation-oriented teaching Strategies		
Understanding student thinking in physics		
Learning how to assess student learning in physics		
Deepening my own physics content knowledge		
Observed other teachers teaching physics as part of your own professional development		
Met with a local group of physics teachers on a regular basis to study/discuss issues about physics teaching		

Collaborated on physics teaching issues with a group of physics teachers at a distance		
Served as a mentor and/or peer coach in physics teaching, as part of a formal arrangement that is recognized or supported by the school		

20. Which of the following best describes the effectiveness of these professional learning areas you have undertaken?

Very effective Effective Not sure Ineffective Very ineffective

☐ ☐ ☐ ☐ ☐

Section D: Classroom practices

21. How often do the following practices happen in your physics classroom? Please indicate by ticking [✓] the appropriate boxes.

Classroom practices	Always	Most of the time	Sometimes	Not often	Never
Teaching approaches					
I present new materials on white board					
I demonstrate problem-solving on the white board					
I lay emphasize on mathematical presentation of concepts					
I lay emphasize on qualitative thinking and presentation of concepts					
I use demonstrations and discussions to illustrate concepts/ phenomena					
Teaching and learning is teacher directed					
Teaching and learning is students' directed					
I use students suggestions and ideas in teaching					
I engage students in context based-activities					
Students work with physics problems individually					
Students work with physics problems in groups					

Students have opportunity to explain their own ideas					
Students do experiment by following instructions from the teacher					
Students plan and do their own experiment					
Teacher feedback and guidance					
Tell students how they can improve their performance					
Give quizzes that I mark to see how students are performing					
Talk to students on how they are getting on in physics					
Mark students' work and give it back quickly					
Use language that is easy to understand					
Show students how new concepts in physics relate to what we have already done					
ICT usage					
Use computers for laboratory simulations					
We look for information on the internet at school					
Use computers to collect and/or analyze data					
Use computers to demonstrate physics principles					
Students use their phones to search for information at school					

Section E: Constraining factors and ways forward

22. The following are sometimes perceived as constraining the quality teaching and learning of high school physics. To what extent do you agree?

Constraining factors	Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree
Students' misconceptions about physics					
Parental and societal perception about the difficulty of physics					
Inadequate education of physics teachers					
The connection between mathematics and physics					
Lack of teacher motivation					
Inadequate teacher subject knowledge					
An overloaded curriculum					
Insufficient classroom teaching time					
Inadequate physics teachers					
Inadequate laboratory equipment					
Lack of technical support					
Assessment and NCEA requirement					
Lack of teacher mentors					

What other factors would you like to give?

- i.
- ii.
- iii.

23. The following are perceived as changes that need to occur to improve the teaching and learning of high school physics. To what extent do you agree?

Ways Forward	Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree
Better pre-service education					
Physics cluster meetings to collaborate ideas on physics teaching					
More teacher professional development on physics practical					
More physics graduates encouraged and/or supported to be trained as teachers					
Reduction in assessment changes from NZQA and MOE					
Better salary and/or incentives for physics teachers					

In your opinion what changes need to occur to improve teaching and learning of high school physics?

- i.
- ii.
- iii.

24. Which of the following best describes your job satisfaction as a physics teacher?

Very satisfied Satisfied Somewhat satisfied Dissatisfied Very Dissatisfied

☐ ☐ ☐ ☐ ☐

25. Would you like to give any additional information?

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Appendix D: Students' Survey Questionnaire

Dear student,

This questionnaire seeks your opinions and concerns about teaching and learning of physics in New Zealand schools. The questionnaire is part of a PhD research project being completed at the University of Canterbury. Your responses will be treated confidentially and will be used for research purposes only. No person or school will be identified in any reports. Thank you for completing the questionnaire. Your cooperation is greatly appreciated.

Please make a tick in the box beside your selected response. Where there are no options given, write your response in the space below the question.

Section A: Bio data

- 1 Gender: Male ☐ Female ☐
- 2 Age:years.
3. School type: Co-educational (Mixed) ☐
Girls only ☐
Boys only ☐
4. What is your year (level) of study?
Year 12 ☐
Year 13 ☐
5. What is your school's decile ranking?
1-3 ☐ 4-7 ☐ 8-10 ☐
6. What is the authority of the school?
State ☐ Private ☐ Integrated ☐
7. (a) Would you like to consider studying physics again, at university?
Yes ☐ No ☐
(b) Give reason(s) for your answer in 7(a).

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8. (a) Would you like to be a physics teacher in the future? Yes ☐ No ☐
(b) Give reason(s) for your answer in 8(a)

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Section B: Interest in Physics Topics

9. To what extent are you interested in the following topics? Please indicate by ticking [✓] the appropriate boxes.

Topics	Very Interested	Somewhat Interested	Not Sure	Somewhat Not Interested	Definitely Not Interested
Mechanics					
Waves					
Electricity and Magnetism					
Electronics					
Atomic and nuclear physics					
Modern physics					
Investigations					
Applications					

Section C: Classroom Activities I

10. How often do the following teaching and learning activities happen in your physics classroom? Please indicate by ticking [✓] the appropriate boxes.

Teaching and learning activities	Always	Most of the time	Sometimes	Not often	Never
Teaching approaches					
Teacher presents new materials on the white board					
Teacher demonstrates problem-solving on the white board (e.g. solving examples of physics problems)					
Teacher emphasizes the mathematical problem solving of new concepts					

Teacher emphasizes understanding of new concepts (qualitative thinking)					
Teacher uses demonstrations and discussions to illustrate concepts/phenomena					
Teaching and learning is teacher directed (the decides what happens)					
Teaching and learning is students directed (the students get a say in what happens)					
Teacher uses students' suggestions and ideas in teaching					
Teacher engages students in context based-activities (e.g. experiments or field trips)					
Students work with physics problems individually					
students work with physics problems in groups					
I have opportunity to explain my own ideas					
We choose our own topics to investigate					
We do experiments by following instructions from the teacher					
We plan and do our own experiments					
Teacher feedback and guidance					
Teacher tells me how I can improve my performance					
Gives us quizzes that we mark to see how we are performing					
Talks to me on how I am getting on in physics					
Marks our work and give it back quickly					
Uses language that is easy to understand					
Shows us how new concepts in physics relate to what we have already done					
ICT usage					
We use computers for laboratory simulations					
We look for information on the internet at school					
We use computers to collect and/or analyze data					

Teacher uses computers to demonstrate physics principles					
I use my phone to search for information at school					

Section D: Classroom Activities II

11. How frequently **would you like** the various strategies to be applied if **you could choose**?
Please indicate by ticking [✓] the appropriate boxes.

Teaching and learning activities	Always	Most of the time	Sometimes	Not often	Never
Dealing with content: Teaching approaches					
Teacher presenting new materials on white board					
Teacher demonstrating problem-solving on the white board (e.g. solving examples of physics problems)					
Emphasis on the mathematical problem solving of new concepts					
Emphasis on the understanding of new concepts (qualitative thinking)					
Use of demonstrations and discussions to illustrate concepts/phenomena					
Teaching and learning being teacher centered					
Teaching and learning being student centered					
Teacher using students' suggestions and ideas in teaching					
Teacher engaging students in context based-activities					
Working with physics problems individually					
Working with physics problems in groups					
Having opportunity to explain your own ideas					
Doing experiments by following instructions from the teacher					
Planning and doing your own experiments					

Teacher feedback and guidance					
Teacher telling me how I can improve my performance					
Giving us quizzes that we mark to see how we are performing					
Talking to me on how I am getting on in physics					
Marking our work and giving it back quickly					
Using language that is easy to understand					
Showing us how new concepts in physics relate to what we have already done					
ICT usage					
Using computers for laboratory simulations					
Looking for information on the internet at school					
Using computers to collect and/or analyze data					
Using computers to demonstrate physics principles					
Using your phone to search for information at school					

Section E: Constraining factors and ways forward

12. To what extent do you agree with the following statements? Please indicate by ticking [✓] the appropriate boxes.

Statements	Strongly agree	Agree	Not sure	Disagree	Strongly disagree
I am curious about what we do in physics					
I am bored about what we do in physics					
I don't understand the physics we do					
I find physics challenging					
I think physics is too hard/difficult					

I am not good at mathematics					
Physics is too mathematical					
Physics is too mathematical and scares me					

Please write your own responses to the following questions.

13. What are the things that you really like about physics in your class?

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14. What are the things that you don't like about physics in your class?

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15. How could your physics class be improved so that you learn more?

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Appendix E: Interview Protocol for Physics Teachers

1. Could you please introduce yourself – your name, school, responsibilities at school, teaching load per week, your personal and educational background, etc.?
2. Could you please tell me about how you decided to become a science teacher with physics, in particular?
3. What was the course content in your degree at your initial teacher education program?
4. What were some of the key ideas that you learned from your teaching qualification?
5. As a previous student, what were some of the most impressive science (or physics) experience you ever encountered, and why?
6. What was your achievement in science and physics, in particular, when you were a student? In your opinion why did you achieve in that way?
7. Could you describe effective learning in your classroom?
8. As a physics teacher, what is/are the effective way(s) for you and your students to teach and learn physics?
9. What difficulties do you experience in teaching physics in a manner consisted with the curriculum?
10. Could you tell me your professional development experience(s) in the past years? What areas of professional learning have you undertaken? What was it exactly? Can you describe the format and frequency?
11. There has been a disturbing decline in the numbers of students taking physics both at high school and tertiary level, and low numbers of physics graduates wanting to train as physics teachers. Why do you think this is? How do you think the numbers can be improved?
12. How do you think the quality of physics teaching can be improved?

Appendix F: Interview Protocol for Physics Students

1. Do you enjoy physics lessons? What makes you enjoy or not enjoy physics lessons?
2. Do you enjoy studying physics? Why?
3. Are you happy with your performance in physics so far? Why?
4. What are the different ways your teacher uses to teach physics?
5. Would you like to consider studying physics again at the university? Why?
6. What do you think makes learning of physics difficult for you?
7. How do you like your physics teacher to change his/her teaching style or make physics interesting to learn?
8. Would you like to become physics teacher in future? Why?

Appendix G: Interview Protocol for Teacher Educators

1. For how long have you been a teacher educator?
2. What is the average number of physics teachers trained per year?
3. Could you describe the physics teacher education programme? How do you feel about the components/contents, duration and structure of the programme?
4. Who decides what to include in the physics education course? How are decisions made about what components to include in the physics education course?
5. What types of teaching strategies/approaches do you use in your teacher education classes? How do you feel about those approaches?
6. How are the student teachers assessed in the physics education course(s)? What types of assessments tasks do they perform? How do you feel about those?
7. How is the teaching practice organised? Who supervises and assesses the student teachers' performance during practicum?
8. Do you have any form of professional learning programs for high school physics teachers? Can you describe its format?
9. There has been a disturbing decline in the numbers of students taking physics both at high school and tertiary level, and low numbers of physics graduates wanting to train as physics teachers. Why do you think this is?
10. How do you think the quality of teaching and learning of physics and the numbers involved can be improved?

Appendix H: Classroom Observation Checklist

1. BACKGROUND INFORMATION

Name of school _____

Name of teacher _____ Years of teaching experience _____

Topic observed _____ Year/Grade _____

Observer _____ Date of observation _____

Start time _____ End time _____

2. LESSON DESIGN AND IMPLEMENTATION

	Never occurred			Very descriptive	
1. The instructional strategies and activities respected students' prior knowledge and the preconceptions inherent therein.	0	1	2	3	4
2. The lesson was designed to engage students as members of a learning community.	0	1	2	3	4
3. In this lesson, student exploration preceded formal presentation.	0	1	2	3	4
4. This lesson encouraged students to seek and value alternative modes of investigation or of problem solving.	0	1	2	3	4
5. The focus and direction of the lesson was often determined by ideas originating with students.	0	1	2	3	4

3. PROPOSITIONAL CONTENT KNOWLEDGE

		Never occurred			Very descriptive	
6.	The lesson involved fundamental concepts of the subject.	0	1	2	3	4
7.	The lesson promoted strongly coherent conceptual understanding.	0	1	2	3	4
8.	The teacher had a solid grasp of the subject matter content inherent in the lesson.	0	1	2	3	4
9.	Elements of abstraction (i.e., symbolic representations, theory building) were encouraged when it was important to do so.	0	1	2	3	4
10.	Connections with other content disciplines and/or real world phenomena were explored and valued.	0	1	2	3	4

4. PROCEDURAL KNOWLEDGE

		Never occurred			Very descriptive	
11.	Students used a variety of means (models, drawings, graphs, concrete materials, manipulative, etc.) to represent phenomena.	0	1	2	3	4
12.	Students made predictions, estimations and/or hypotheses and devised means for testing them.	0	1	2	3	4
13.	Students were actively engaged in thought-provoking activity that often involved the critical assessment of procedures.	0	1	2	3	4
14.	Students were reflective about their learning.	0	1	2	3	4
15.	Intellectual rigor, constructive criticism, and the challenging of ideas were valued.	0	1	2	3	4

5. CLASSROOM CULTURE (Communicative Interactions)

	Never occurred			Very descriptive	
16. Students were involved in the communication of their ideas to others using a variety of means and media.	0	1	2	3	4
17. The teacher's questions triggered divergent modes of thinking.	0	1	2	3	4
18. There was a high proportion of student talk and a significant amount of it occurred between and among students.	0	1	2	3	4
19. Student questions and comments often determined the focus and direction of classroom discourse.	0	1	2	3	4
20. There was a climate of respect for what others had to say.	0	1	2	3	4

6. CLASSROOM CULTURE (Student/Teacher Relationships)

	Never occurred			Very descriptive	
21. Active participation of students was encouraged and valued.	0	1	2	3	4
22. Students were encouraged to generate conjectures, alternative solution strategies, and ways of interpreting evidence.	0	1	2	3	4
23. In general the teacher was patient with students.	0	1	2	3	4
24. The teacher acted as a resource person, working to support and enhance student investigations.	0	1	2	3	4
25. The metaphor "teacher as listener" was very characteristic of this classroom.	0	1	2	3	4

Appendix I: Calculation of Effect Size Statistics

$$\text{Effect size } (r) = \sqrt{\frac{t^2}{t^2 + (df)}} \quad \text{where}$$

t is the value of the t-test statistics, = 2.05

df refers to degree of freedom which is computed as $df = (N_1 + N_2 - 2)$ where N_1 and N_2 are the number of population in each group.

$$N_1 = 75; \quad N_2 = 29$$

$$r = \sqrt{\frac{2.05^2}{2.05^2 + 102}}$$

$$r = \sqrt{\frac{4.2025}{106.2025}}$$

$$r = 0.1989$$

Appendix J: Preliminary Assumptions Testing for UTL Constructs

Correlations

		Knowledge of learners and their dev.	Knowledge of subject matter	Knowledge of teaching
Knowledge of learners and their dev.	Pearson Correlation	1	.482**	.593**
	Sig. (2-tailed)		.000	.000
	N	104	104	104
Knowledge of subject matter	Pearson Correlation	.482**	1	.664**
	Sig. (2-tailed)	.000		.000
	N	104	104	104
Knowledge of teaching	Pearson Correlation	.593**	.664**	1
	Sig. (2-tailed)	.000	.000	
	N	104	104	104

** . Correlation is significant at the 0.01 level (2-tailed).

Box's Test of Equality of Covariance Matrices^a

Box's M	32.578
F	1.711
df1	18
df2	34635.687
Sig.	.030

Tests the null hypothesis that the observed covariance matrices of the dependent variables are equal across groups.

a. Design: Intercept+yearITEgp

Levene's Test of Equality of Error Variances^a

	F	df1	df2	Sig.
Knowledge of learners and their dev.	1.852	3	100	.143
Knowledge of subject matter	1.117	3	100	.346
Knowledge of teaching	1.466	3	100	.229

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Design: Intercept+yearITEgp

Appendix K: Post Hoc Test with Bonferroni and Games-Howell Corrections

Multiple Comparisons						
Dependent Variable		(I) yearITEgp	(J) yearITEgp	Mean Difference (I-J)	Std. Error	Sig.
Knowledge of learners and their dev.	Bonferroni	1965-1987	1988-2000	-.0370	.19221	1.000
			2001-2007	-.3627	.19813	.421
			2008+	-.4278	.19405	.179
		1988-2000	1965-1987	.0370	.19221	1.000
			2001-2007	-.3256	.19813	.621
			2008+	-.3908	.19405	.280
		2001-2007	1965-1987	.3627	.19813	.421
			1988-2000	.3256	.19813	.621
			2008+	-.0652	.19991	1.000
		2008+	1965-1987	.4278	.19405	.179
			1988-2000	.3908	.19405	.280
			2001-2007	.0652	.19991	1.000
	Games-Howell	1965-1987	1988-2000	-.0370	.21536	.998
			2001-2007	-.3627	.22104	.366
			2008+	-.4278	.20498	.174
		1988-2000	1965-1987	.0370	.21536	.998
			2001-2007	-.3256	.18367	.299
			2008+	-.3908	.16398	.094
		2001-2007	1965-1987	.3627	.22104	.366
			1988-2000	.3256	.18367	.299
			2008+	-.0652	.17138	.981
Knowledge of subject matter	Bonferroni	1965-1987	1988-2000	-.4444	.18217	.099
			2001-2007	-.5093*	.18778	.047
			2008+	-.7507*	.18391	.001
		1988-2000	1965-1987	.4444	.18217	.099
			2001-2007	-.0648	.18778	1.000
			2008+	-.3063	.18391	.594
		2001-2007	1965-1987	.5093*	.18778	.047
			1988-2000	.0648	.18778	1.000
			2008+	-.2415	.18947	1.000
		2008+	1965-1987	.7507*	.18391	.001
			1988-2000	.3063	.18391	.594
			2001-2007	.2415	.18947	1.000
	Games-Howell	1965-1987	1988-2000	-.4444	.20260	.139
			2001-2007	-.5093*	.19028	.049
			2008+	-.7507*	.19629	.002
		1988-2000	1965-1987	.4444	.20260	.139
			2001-2007	-.0648	.17008	.981
			2008+	-.3063	.17677	.318
		2001-2007	1965-1987	.5093*	.19028	.049
			1988-2000	.0648	.17008	.981
			2008+	-.2415	.16251	.454
Knowledge of teaching	Bonferroni	1965-1987	1988-2000	-.3704	.19877	.392
			2001-2007	-.3426	.20489	.586
			2008+	-.4580	.20067	.148
		1988-2000	1965-1987	.3704	.19877	.392
			2001-2007	.0278	.20489	1.000
			2008+	-.0876	.20067	1.000
		2001-2007	1965-1987	.3426	.20489	.586
			1988-2000	-.0278	.20489	1.000
			2008+	-.1154	.20674	1.000
		2008+	1965-1987	.4580	.20067	.148
			1988-2000	.0876	.20067	1.000
			2001-2007	.1154	.20674	1.000
	Games-Howell	1965-1987	1988-2000	-.3704	.21660	.329
			2001-2007	-.3426	.18793	.275
			2008+	-.4580	.19660	.105
		1988-2000	1965-1987	.3704	.21660	.329
			2001-2007	.0278	.20479	.999
			2008+	-.0876	.21278	.976
		2001-2007	1965-1987	.3426	.18793	.275
			1988-2000	-.0278	.20479	.999
			2008+	-.1154	.18352	.922
2008+	1965-1987	.4580	.19660	.105		
	1988-2000	.0876	.21278	.976		
	2001-2007	.1154	.18352	.922		

Based on observed means.

*. The mean difference is significant at the .05 level.

Appendix L: Frequency and Percentage Tables for Classroom Interactions

1. Teaching approaches

I present new materials on white board

	Frequency	Percent	Valid Percent	Cumulative Percent
Never	3	2.9	2.9	2.9
Not Often	7	6.7	6.7	9.6
Sometimes	35	33.7	33.7	43.3
Most of the Time	48	46.2	46.2	89.4
Always	11	10.6	10.6	100.0
Total	104	100.0	100.0	

I demonstrate problem-solving on the white board

	Frequency	Percent	Valid Percent	Cumulative Percent
Not Often	1	1.0	1.0	1.0
Sometimes	32	30.8	30.8	31.7
Most of the Time	48	46.2	46.2	77.9
Always	23	22.1	22.1	100.0
Total	104	100.0	100.0	

I lay emphasis on mathematical presentation of concepts

	Frequency	Percent	Valid Percent	Cumulative Percent
Not Often	16	15.4	15.4	15.4
Sometimes	35	33.7	33.7	49.0
Valid Most of the Time	35	33.7	33.7	82.7
Always	18	17.3	17.3	100.0
Total	104	100.0	100.0	

I lay emphasis on qualitative thinking and presentation of concepts

	Frequency	Percent	Valid Percent	Cumulative Percent
Not Often	5	4.8	4.8	4.8
Sometimes	30	28.8	28.8	33.7
Valid Most of the Time	48	46.2	46.2	79.8
Always	21	20.2	20.2	100.0
Total	104	100.0	100.0	

I use demonstrations and discussions to illustrate concepts/ phenomena

	Frequency	Percent	Valid Percent	Cumulative Percent
Not Often	1	1.0	1.0	1.0
Sometimes	33	31.7	31.7	32.7
Valid Most of the Time	50	48.1	48.1	80.8
Always	20	19.2	19.2	100.0
Total	104	100.0	100.0	

Teaching and learning is teacher directed

	Frequency	Percent	Valid Percent	Cumulative Percent
Not Often	5	4.8	4.8	4.8
Sometimes	43	41.3	41.3	46.2
Valid Most of the Time	55	52.9	52.9	99.0
Always	1	1.0	1.0	100.0
Total	104	100.0	100.0	

Teaching and learning is students' directed

	Frequency	Percent	Valid Percent	Cumulative Percent
Not Often	34	32.7	32.7	32.7
Sometimes	58	55.8	55.8	88.5
Valid Most of the Time	12	11.5	11.5	100.0
Total	104	100.0	100.0	

I use students' suggestions and ideas in teaching

	Frequency	Percent	Valid Percent	Cumulative Percent
Not Often	11	10.6	10.6	10.6
Sometimes	62	59.6	59.6	70.2
Valid Most of the Time	22	21.2	21.2	91.3
Always	9	8.7	8.7	100.0
Total	104	100.0	100.0	

I engage students in context based-activities

	Frequency	Percent	Valid Percent	Cumulative Percent
Not Often	14	13.5	13.5	13.5
Sometimes	53	51.0	51.0	64.4
Valid Most of the Time	31	29.8	29.8	94.2
Always	6	5.8	5.8	100.0
Total	104	100.0	100.0	

Students work with physics problems individually

	Frequency	Percent	Valid Percent	Cumulative Percent
Never	2	1.9	1.9	1.9
Not Often	6	5.8	5.8	7.7
Sometimes	59	56.7	56.7	64.4
Valid Most of the Time	36	34.6	34.6	99.0
Always	1	1.0	1.0	100.0
Total	104	100.0	100.0	

Students work with physics problems in groups

	Frequency	Percent	Valid Percent	Cumulative Percent
Not Often	9	8.7	8.7	8.7
Sometimes	61	58.7	58.7	67.3
Valid Most of the Time	33	31.7	31.7	99.0
Always	1	1.0	1.0	100.0
Total	104	100.0	100.0	

Students have opportunity to explain their own ideas

	Frequency	Percent	Valid Percent	Cumulative Percent
Not Often	5	4.8	4.8	4.8
Sometimes	45	43.3	43.3	48.1
Valid Most of the Time	41	39.4	39.4	87.5
Always	13	12.5	12.5	100.0
Total	104	100.0	100.0	

Students do experiments by following instructions from the teacher

	Frequency	Percent	Valid Percent	Cumulative Percent
Never	1	1.0	1.0	1.0
Not Often	12	11.5	11.5	12.5
Sometimes	49	47.1	47.1	59.6
Valid Most of the Time	39	37.5	37.5	97.1
Always	3	2.9	2.9	100.0
Total	104	100.0	100.0	

Students plan and do their own experiments

	Frequency	Percent	Valid Percent	Cumulative Percent
Never	9	8.7	8.7	8.7
Not Often	43	41.3	41.3	50.0
Sometimes	39	37.5	37.5	87.5
Valid Most of the Time	12	11.5	11.5	99.0
Always	1	1.0	1.0	100.0
Total	104	100.0	100.0	

2. Teacher feedback and guidance

Tell students how they can improve their performance

	Frequency	Percent	Valid Percent	Cumulative Percent
Sometimes	27	26.0	26.0	26.0
Most of the Time	56	53.8	53.8	79.8
Always	21	20.2	20.2	100.0
Total	104	100.0	100.0	

Give quizzes that I mark to see how students are performing

	Frequency	Percent	Valid Percent	Cumulative Percent
Never	3	2.9	2.9	2.9
Not Often	27	26.0	26.0	28.8
Sometimes	55	52.9	52.9	81.7
Most of the Time	16	15.4	15.4	97.1
Always	3	2.9	2.9	100.0
Total	104	100.0	100.0	

Talk to students on how they are getting on in physics

	Frequency	Percent	Valid Percent	Cumulative Percent
Not Often	5	4.8	4.8	4.8
Sometimes	40	38.5	38.5	43.3
Most of the Time	42	40.4	40.4	83.7
Always	17	16.3	16.3	100.0
Total	104	100.0	100.0	

Mark students' work and give it back quickly

	Frequency	Percent	Valid Percent	Cumulative Percent
Not Often	4	3.8	3.8	3.8
Sometimes	23	22.1	22.1	26.0
Valid Most of the Time	49	47.1	47.1	73.1
Always	28	26.9	26.9	100.0
Total	104	100.0	100.0	

Use language that is easy to understand

	Frequency	Percent	Valid Percent	Cumulative Percent
Sometimes	11	10.6	10.6	10.6
Valid Most of the Time	57	54.8	54.8	65.4
Always	36	34.6	34.6	100.0
Total	104	100.0	100.0	

Show students how new concepts in physics relate to what we have already done

	Frequency	Percent	Valid Percent	Cumulative Percent
Not Often	2	1.9	1.9	1.9
Sometimes	19	18.3	18.3	20.2
Valid Most of the Time	49	47.1	47.1	67.3
Always	34	32.7	32.7	100.0
Total	104	100.0	100.0	

3. ICT usage in physics teaching

Use computers for laboratory simulations

	Frequency	Percent	Valid Percent	Cumulative Percent
Valid Never	8	7.7	7.7	7.7
Not Often	24	23.1	23.1	30.8
Sometimes	53	51.0	51.0	81.7
Most of the Time	16	15.4	15.4	97.1
Always	3	2.9	2.9	100.0
Total	104	100.0	100.0	

We look for information on the internet at school

	Frequency	Percent	Valid Percent	Cumulative Percent
Valid Never	4	3.8	3.8	3.8
Not Often	26	25.0	25.0	28.8
Sometimes	58	55.8	55.8	84.6
Most of the Time	11	10.6	10.6	95.2
Always	5	4.8	4.8	100.0
Total	104	100.0	100.0	

Use computers to collect and/or analyze data

	Frequency	Percent	Valid Percent	Cumulative Percent
Valid				
Never	13	12.5	12.5	12.5
Not Often	41	39.4	39.4	51.9
Sometimes	37	35.6	35.6	87.5
Most of the Time	11	10.6	10.6	98.1
Always	2	1.9	1.9	100.0
Total	104	100.0	100.0	

Use computers to demonstrate physics principles

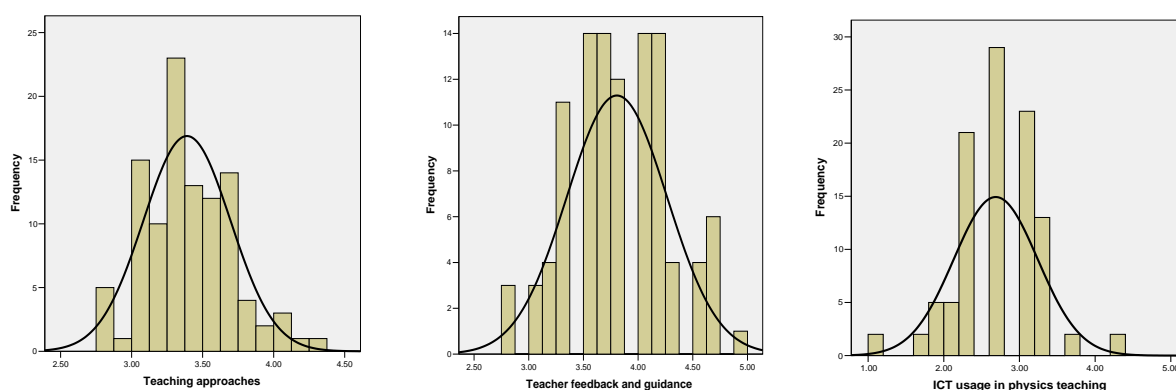
	Frequency	Percent	Valid Percent	Cumulative Percent
Valid				
Never	3	2.9	2.9	2.9
Not Often	17	16.3	16.3	19.2
Sometimes	71	68.3	68.3	87.5
Most of the Time	11	10.6	10.6	98.1
Always	2	1.9	1.9	100.0
Total	104	100.0	100.0	

Students use their phones to search for information at school

	Frequency	Percent	Valid Percent	Cumulative Percent
Valid				
Never	28	26.9	26.9	26.9
Not Often	24	23.1	23.1	50.0
Sometimes	46	44.2	44.2	94.2
Most of the Time	4	3.8	3.8	98.1
Always	2	1.9	1.9	100.0
Total	104	100.0	100.0	

Appendix M: Preliminary Assumptions Testing For Classroom Interaction Constructs

Normality



Correlations

		Teaching approaches	Teacher feedback and guidance	ICT Usage
Teaching approaches	Pearson Correlation	1	.548**	.174
	Sig. (2-tailed)		.000	.078
	N	104	104	104
Teacher feedback and guidance	Pearson Correlation	.548**	1	.180
	Sig. (2-tailed)	.000		.067
	N	104	104	104
ICT usage	Pearson Correlation	.174	.180	1
	Sig. (2-tailed)	.078	.067	
	N	104	104	104

** . Correlation is significant at the 0.01 level (2-tailed).

Box's Test of Equality of Covariance Matrices^a

Box's M	18.553
F	1.405
df1	12
df2	2199.277
Sig.	.156

Tests the null hypothesis that the observed covariance matrices of the dependent variables are equal across groups.

Levene's Test of Equality of Error Variances^a

	F	df1	df2	Sig.
Teaching approaches	.310	2	101	.734
Teacher feedback and guidance	2.089	2	101	.129
ICT tools	3.534	2	101	.033

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

Appendix N: Permission Note to Reproduce Figure

From: Linda Darling-Hammond [mailto:lindadh@gse.stanford.edu]
Sent: Friday, 13 March 2015 11:16 a.m.
To: Isaac Buabeng
Subject: RE: Permission to reproduce your figure

Dear Isaac,

Thank you for your interest and dedication to education. Your request to reprint the "Framework for Understanding Teaching and Learning" figure for your research thesis and presentation at AERA is greatly appreciated. It is Dr. Darling-Hammond's policy is to always grant permission to reprint her material, so please feel free to do so. Please be assured that she will also be notified accordingly.

All the best,

Maude Engström

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Appendix O: RTOP User Guide

LESSON DESIGN AND IMPLEMENTATION

1. *The instructional strategies and activities respected students' prior knowledge and the preconceptions inherent therein.*

A cornerstone of reformed teaching is taking into consideration the prior knowledge that students bring with them. The term “respected” is pivotal in this item. It suggests an attitude of curiosity on the teacher’s part, an active solicitation of student ideas, and an understanding that much of what a student brings to the mathematics or science classroom is strongly shaped and conditioned by their everyday experiences.

2. *The lesson was designed to engage students as members of a learning community.*

Much knowledge is socially constructed. The setting within which this occurs has been called a “learning community.” The use of the term community in the phrase “the scientific community” (a “self-governing” body) is similar to the way it is intended in this item. Students participate actively, their participation is integral to the actions of the community, and knowledge is negotiated within the community. It is important to remember that a group of learners does not necessarily constitute a “learning community.”

3. *In this lesson, student exploration preceded formal presentation.*

Reformed teaching allows students to build complex abstract knowledge from simpler, more concrete experience. This suggests that any formal presentation of content should be preceded by student exploration. This does not imply the converse...that all exploration should be followed by a formal presentation.

4. *This lesson encouraged students to seek and value alternative modes of investigation or of problem solving.*

Divergent thinking is an important part of mathematical and scientific reasoning. A lesson that meets this criterion would not insist on only one method of experimentation or one approach to solving a problem. A teacher who valued alternative modes of thinking would respect and actively solicit a variety of approaches, and understand that there may be more than one answer to a question.

5. *The focus and direction of the lesson was often determined by ideas originating with students.*

If students are members of a true learning community, and if divergence of thinking is valued, then the direction that a lesson takes cannot always be predicted in advance. Thus, planning and executing a lesson may include contingencies for building upon the unexpected. A lesson that met this criterion might not end up where it appeared to be heading at the beginning.

PROPOSITIONAL KNOWLEDGE (Knowledge of what is)

6. The lesson involved fundamental concepts of the subject.

The emphasis on “fundamental” concepts indicates that there were some significant scientific or mathematical ideas at the heart of the lesson. For example, a lesson on the multiplication algorithm can be anchored in the distributive property. A lesson on energy could focus on the distinction between heat and temperature.

7. The lesson promoted strongly coherent conceptual understanding.

The word “coherent” is used to emphasize the strong inter-relatedness of mathematical and/or scientific thinking. Concepts do not stand on their own two feet. They are increasingly more meaningful as they become integrally related to and constitutive of other concepts.

8. The teacher had a solid grasp of the subject matter content inherent in the lesson.

This indicates that a teacher could sense the potential significance of ideas as they occurred in the lesson, even when articulated vaguely by students. A solid grasp would be indicated by an eagerness to pursue student’s thoughts even if seemingly unrelated at the moment. The grade-level at which the lesson was directed should be taken into consideration when evaluating this item.

9. Elements of abstraction (i.e., symbolic representations, theory building) were encouraged when it was important to do so.

Conceptual understanding can be facilitated when relationships or patterns are represented in abstract or symbolic ways. Not moving toward abstraction can leave students overwhelmed with trees when a forest might help them locate themselves.

10. Connections with other content disciplines and/or real world phenomena were explored and valued.

Connecting mathematical and scientific content across the disciplines and with real world applications tends to generalize it and make it more coherent. A physics lesson on electricity might connect with the role of electricity in biological systems, or with the wiring systems of a house. A mathematics lesson on proportionality might connect with the nature of light, and refer to the relationship between the height of an object and the length of its shadow.

PROCEDURAL KNOWLEDGE (Knowledge of how)

11. Students used a variety of means (models, drawings, graphs, symbols, concrete materials, manipulatives, etc.) to represent phenomena.

Multiple forms of representation allow students to use a variety of mental processes to articulate their ideas, analyze information and to critique their ideas. A “variety” implies that at least two different means were used. Variety also occurs within a given means. For example, several different kinds of graphs could be used, not just one kind.

12. Students made predictions, estimations and/or hypotheses and devised means for testing them.

This item does not distinguish among predictions, hypotheses and estimations. All three terms are used so that the RTOP can be descriptive of both mathematical thinking and scientific reasoning. Another word that might be used in this context is “conjectures”. The idea is that students explicitly state what they think is going to happen before collecting data.

13. Students were actively engaged in thought-provoking activity that often involved the critical assessment of procedures.

This item implies that students were not only actively doing things, but that they were also actively thinking about how what they were doing could clarify the next steps in their investigation.

14. Students were reflective about their learning.

Active reflection is a meta-cognitive activity that facilitates learning. It is sometimes referred to as “thinking about thinking.” Teachers can facilitate reflection by providing time and suggesting strategies for students to evaluate their thoughts throughout a lesson. A review conducted by the teacher may not be reflective if it does not induce students to re-examine or re-assess their thinking.

15. Intellectual rigor, constructive criticism, and the challenging of ideas were valued.

At the heart of mathematical and scientific endeavours is rigorous debate. In a lesson, this would be achieved by allowing a variety of ideas to be presented, but insisting that challenge and negotiation also occur. Achieving intellectual rigor by following a narrow, often prescribed path of reasoning, to the exclusion of alternatives, would result in a low score on this item. Accepting a variety of proposals without accompanying evidence and argument would also result in a low score.

CLASSROOM CULTURE (Communicative Interactions)

16. Students were involved in the communication of their ideas to others using a variety of means and media.

The intent of this item is to reflect the communicative richness of a lesson that encouraged students to contribute to the discourse and to do so in more than a single mode (making presentations, brainstorming, critiquing, listening, making videos, group work, etc.). Notice the difference between this item and item 11. Item 11 refers to representations. This item refers to active communication.

17. The teacher's questions triggered divergent modes of thinking.

This item suggests that teacher questions should help to open up conceptual space rather than confining it within predetermined boundaries. In its simplest form, teacher questioning triggers divergent modes of thinking by framing problems for which there may be more than one correct answer or framing phenomena that can have more than one valid interpretation.

18. There was a high proportion of student talk and a significant amount of it occurred between and among students.

A lesson where a teacher does most of the talking is not reformed. This item reflects the need to increase both the amount of student talk and of talk among students. A “high proportion” means that at any point in time it was as likely that a student would be talking as that the teacher would be. A “significant amount” suggests that critical portions of the lesson were developed through discourse among students.

19. Student questions and comments often determined the focus and direction of classroom discourse.

This item implies not only that the flow of the lesson was often influenced or shaped by student contributions, but that once a direction was in place, students were crucial in sustaining and enhancing the momentum.

20. There was a climate of respect for what others had to say.

Respecting what others have to say is more than listening politely. Respect also indicates that what others had to say was actually heard and carefully considered. A reformed lesson would encourage and allow every member of the community to present their ideas and express their opinions without fear of censure or ridicule.

CLASSROOM CULTURE (Student/Teacher Relationships)

21. Active participation of students was encouraged and valued.

This implies more than just a classroom full of active students. It also connotes their having a voice in how that activity is to occur. Simply following directions in an active manner does not meet the intent of this item. Active participation implies agenda-setting as well as “minds-on” and “hands-on”.

22. Students were encouraged to generate conjectures, alternative solution strategies, and/or different ways of interpreting evidence.

Reformed teaching shifts the balance of responsibility for mathematical or scientific thought from the teacher to the students. A reformed teacher actively encourages this transition. For example, in a mathematics lesson, the teacher might encourage students to find more than one way to solve a problem. This encouragement would be highly rated if the whole lesson was devoted to discussing and critiquing these alternate solution strategies.

23. In general the teacher was patient with students.

Patience is not the same thing as tolerating unexpected or unwanted student behaviour. Rather there is anticipation that, when given a chance to play itself out, unanticipated behaviour can lead to rich learning opportunities. A long “wait time” is a necessary but not sufficient condition for rating highly on this item.

24. The teacher acted as a resource person, working to support and enhance student investigations.

A reformed teacher is not there to tell students what to do and how to do it. Much of the initiative is to come from students, and because students have different ideas, the teacher’s support is carefully crafted to the idiosyncrasies of student thinking. The metaphor, “guide on the side” is in accord with this item.

25. The metaphor “teacher as listener” was very characteristic of this classroom.

This metaphor describes a teacher who is often found helping students use what they know to construct further understanding. The teacher may indeed talk a lot, but such talk is carefully crafted around understandings reached by actively listening to what students are saying. “Teacher as listener” would be fully in place if “student as listener” was reciprocally engendered.